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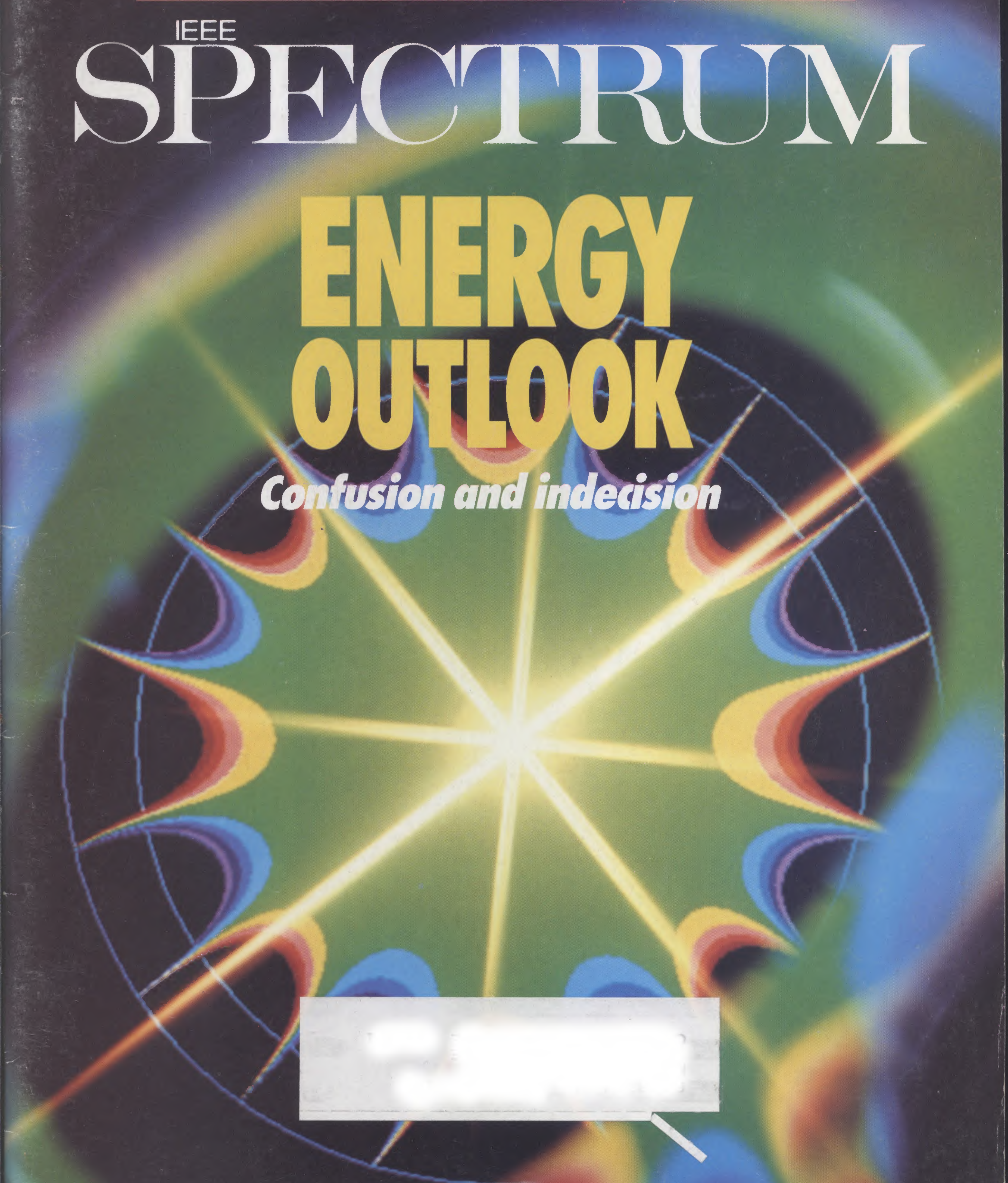
IEEE

SPECTRUM

ENERGY OUTLOOK

Confusion and indecision



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Circle No. 2

SPEA 3/91

SCIENCE/SCOPE®

A thermal imaging system that turns night into day for crews of U.S. Navy SH-2F Light Airborne Multi-Purpose System (LAMPS) helicopters is aiding in the fight against drugs. LAMPS helicopters, equipped with the Hughes Aircraft Company's AN/AAQ-16 Hughes Night Vision System (HNVS), have been participating in law enforcement operations in support of the Coast Guard Carribean Squadron, flying hundreds of vital law enforcement surveillance sorties, sighting and reporting many suspect surface vessels which otherwise would have gone undetected. HNVS has been installed on a variety of U.S. Army, Air Force and Navy helicopters, and a derivative of the system has been selected for the U.S. Tri-Service V-22 Osprey.

A self-contained plasma source will help prolong the life of satellites in space. The source, part of the Flight Model Discharge System (FMDS), developed and built by Hughes for the U.S. Air Force, produces a dilute low-energy plasma cloud near the spacecraft's surface. The cloud effectively "grounds" the vehicle by forming a conductive bridge that electrically couples the vehicle's outer surfaces to each other and to the plasma of space. Without FMDS, electrical charges from ionized gases could build up on the spacecraft, causing arcing that could damage delicate electronic equipment.

A night vision system has demonstrated it can increase the operational effectiveness and survivability of M1 Abrams tanks and Bradley Fighting Vehicles. The Driver's Thermal Viewer (DTV), under development at Hughes for the U.S. Army, is a low-cost thermal imaging system that enables drivers to see through darkness, dust, battlefield smoke, haze, and rain. During simulated combat exercises, the DTV demonstrated that it improved both vehicle maneuverability and crew safety and target acquisition. The DTV, designated AN/VAS-3, can replace the existing AN/VVS-2 image intensifier driver's viewer without modification to the vehicle's armor or driver station.

State-of-the-art air defense systems built by Hughes protect more than one billion of the free world's population. The Air Defense Ground Environment (ADGE) systems, designed by Hughes for 23 nations, network operations centers, ground-based and airborne sensors, surface-to-air missile bases, and air bases into real-time command and control systems. ADGE systems identify all aircraft approaching their nation's borders, display the aircraft's altitude, speed, and course, and electronically interrogate the aircraft to determine its identity. Future ADGE systems will include a new distributed architecture that will allow them to use more mobile and transportable elements, as well as off-the-shelf commercial computers, for more cost-effective operation.

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Newslog

JAN 10. The **Federal Communications Commission,** Washington, D.C., proposed making a special broadcast frequency for two-way interactive television services available in every U.S. community, indicating that the agency believes the technology has advanced to the point where it is ready for commercial use.

JAN 11. The **Brazilian Government** authorized the country's first information technology joint venture, in which **IBM Corp.** and **SID Informática SA,** Curitaba, will produce IBM's PS/2 microcomputers. SID said the venture, to be based in São Paulo, will be operational within three months.

JAN 16. The **United States and allied forces** opened a long-threatened war to drive **Iraqi President Saddam Hussein's** army from Kuwait. Experts said the war marks the coming of age of computerized weaponry, which has included Navy Tomahawk cruise missiles, Pave Tack laser-guided bombs, Air Force F-117A Stealth fighters, and the Army Patriot antimissile systems.

JAN 19. The **U.S. government** began a $900 000 study to determine whether barrels of radioactive waste dumped into the Pacific Ocean could break open and spill into the richest marine habitat in the West. Financed by the **National Oceanic and Atmospheric Administration,** Washington, D.C., the study will focus on locating about 48 000 barrels of chemicals and other wastes that in a 24-year period were scattered in the Gulf of the Farallones, 50 kilometers west of San Francisco.

JAN 24. IBM Corp. said it has agreed in principle with the USSR's **Ministry of Civil Aviation** to supply passenger booking and cargo computer systems to **Aeroflot,** the Soviet airline. The company also announced plans to set up a wholly owned subsidiary in the USSR to provide maintenance and marketing services—the first Western company without a Soviet partner.

JAN 25. Mercury Communications Ltd. in London stole a march on the more prominent **British Telecom** by joining forces with the United States' **AT&T Co.,** Germany's **Bundespost Telekom, France Télécom,** and the **Netherlands PTT** in announcing the construction of a new set of transatlantic telecommunications cables.

JAN 28. Apple Computer Inc., Cupertino, Calif., asked the **Federal Communications Commission,** Washington, D.C., to set aside a 40-megahertz swatch of radio frequencies to allow PCs to receive and transmit data without wires, giving users of portable computers more mobility. Apple urged that the frequencies be available to all users without a license.

JAN 29. National Semiconductor Corp., Santa Clara, Calif., said its new computer chip set can increase the performance of computer systems tenfold, to 3.2 billion bytes (25 gigabits) a second. It is the first production-volume chip set designed for the Futurebus Plus IEEE standard.

JAN 30. British Aerospace PLC, London, and the French state-controlled **Thomson-CSF,** Paris, received the go-ahead from the UK **Monopolies and Mergers Commission** to pool their missile businesses in a new company, called **Eurodynamics,** that would dominate the European missile sector.

JAN 31. General Motors Corp., Ford Motor Co., and **Chrysler Corp.** said they are teaming up with the **U.S. government** to spend more than $1 billion over the next 12 years on R&D of advanced battery technologies for use in electric vehicles.

JAN 31. A National Academy of Sciences panel of scientists, academics, and former Government officials urged lifting U.S. export controls on technology for the Soviet civilian sector but said exports that could assist the Soviet military should remain under strict controls. The Washington, D.C.–based group also called for a stronger multilateral effort to keep unstable Third World regimes from acquiring weapons of mass destruction.

JAN 31. IBM Corp. said it has developed a low-cost way to make 1/64-inch (0.4-millimeter) semiconductor lasers. The new process allows production in existing chip-making facilities and enables IBM to test the lasers in batches of 20 000 units, halving production costs.

JAN 31. MIPS Computer Systems Inc., Sunnyvale, Calif., announced the first 64-bit reduced-instruction-set computing chip, the R4000. It is expected to perform 50 million instructions per second; shipments will begin in late 1991.

FEB 4. International Computers Ltd. PLC, the London-based computer company in which Tokyo's **Fujitsu Ltd.** acquired an 80 percent stake last year, was expelled from the **European Information Technology Round Table,** an electronics lobby, on the grounds that the group should consist of companies that were "truly European-owned."

FEB 4. The Bush administration opened an international conference on global warming in Chantilly, Va., by declaring that the United States will stabilize its overall production of "greenhouse gases." Three days later a study released by the **Congressional Office of Technology Assessment** said that current technology could be used to cut global warming gases but that the cost of significantly reducing emissions of carbon dioxide alone could hit $150 billion a year.

FEB 7. The Department of Energy made public a study that envisions a sharply reduced need for nuclear arms in the 21st century and proposes shutting down all but five of the U.S. weapons plants and allowing private companies to own the factories for making the weapons' nonnuclear components.

FEB 7. Soviet Prosecutor General Nikolai Trubin, prodded by individual and local government complaints, conceded that there had been gross failures in the **Soviet Government's** cleanup of the April 1986 **Chernobyl nuclear disaster** and said some officials would face criminal charges for failing to protect the public properly from radioactive fallout.

FEB 9. A nuclear accident occurred at Japan's 19-year-old **Mihama Nuclear Power Plant** near Kyoto when a pipe apparently broke, allowing radioactive water to spill into a secondary cooling system. Government officials and the **Kansai Electric Power Co.** said no one was hurt, but Japanese press reports estimated escaped radioactivity to be about 8 percent of the plant's annual emissions. Experts said the accident was the worst since Japan began operating nuclear plants in 1966.

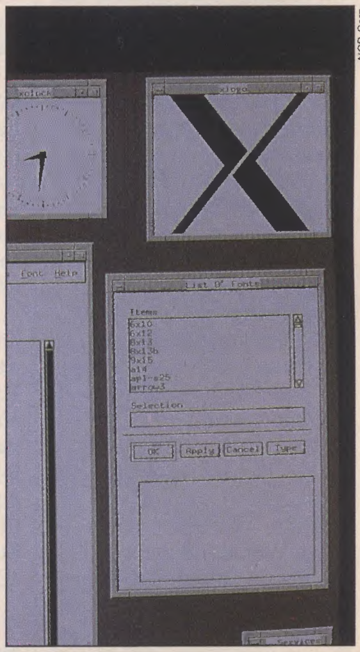
Preview:
MAR 17–20. The first annual meeting of the Washington, D.C.–based **Intelligent Vehicle Highway Society of America** is held in Reston, Va., with 20 sessions on how electronics can be applied to add efficiency to vehicle use and capacity to roadways.

COORDINATOR: Sally Cahur

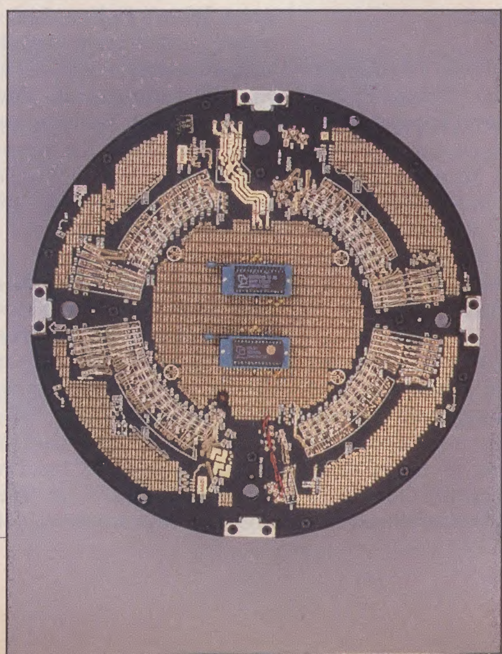
March 1991 Volume 28 Number 3

IEEE SPECTRUM

American Electric Power Co.



NCR Corp.



Teradyne Inc.

SYSTEMS RELIABILITY

56 When bust is best

By Trudy E. Bell

AT&T Bell Laboratories

Wrecking balls, shaker tables, fires, winches—all are proving indispensable in the growing practice of destroying equipment to prove it. The goal: "to find out what's wrong with a product before customers do." One method is to find failure points, namely, the most extreme conditions under which gear can still function. Another determines how rough its handling can be during transport, installation, or operation. Guidelines have evolved for deciding among options, and in some cases high technology has been called in for diagnostic problems.

BACK TO BASICS

60 Laplace's transform

By Paul J. Nahin

This mathematical signature of the EE is popular because it changes some of the most important differential equations of physics into easier-to-solve algebraic equations—above all by mapping the difficult operation of convolution into multiplication. Dating to Napoleon, it attained widespread use among EEs just before World War II. Now, with the spread of sophisticated software, it could return to obscurity.

Cover: The magnetic field distribution in the aperture of a prototype superconducting super collider magnet at the Brookhaven National Laboratory, Upton, N.Y. See p. 36. Photo: Department of Energy

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Reflections

The ambitious word processor

This column is being conceived by my word processor. I am sitting helplessly in front of the computer screen, watching in wonderment as this essay unfolds. So if you do not like it, please do not blame me. The computer has taken over; it is on its own.

When you think about it in retrospect, it is obvious how this insidious revolution came about. We used to write with stubby pencils on the backs of old envelopes. But we live in a world populated with lost ballpoint pens and inundated with junk mail envelopes that have no usable blank spaces. Someone had to invent word processors.

At first, that invention seemed like a good idea. Its most appealing feature was that big electronic eraser in the sky that could come down and magically zap undesirable utterances. Of course, in its zealousness, the eraser often zapped other things just for practice—like whole, precious essays, chapters, and theses. That was the risk we took, but what would we not give to be able to retrace our footsteps at will? Life should have such a feature—the generalized "undo" command.

Flushed with the new power provided by our word processor, we zapped everything in sight. Oh, it was thrilling! But gradually, ever so gradually, we lost something. We lost the idea of permanence. I see in my mind the ancient Egyptians with their mallets and chisels carving the hieroglyphic symbols for all eternity. I see Shakespeare with his quill pen fitting his words into iambic pentameter for the centuries to come.

But writing has now become only a fluid state. There is no longer such a concept as "done"; there remains only a version number and dated file. The only thing that temporarily stops further change is a deadline. But even after a paper has gone to press or been handed in, we look at the file and see an offending word. What mortal being can resist the overpowering urge to zap? Next, word processors began to extend their power and dominance in the affairs of humanity. The word processors probably whispered to each other. "Formatting," they said. Naively, we users began to play with our new toy. Now we could jiggle things around and prettify everything in sight. Oh, how beautiful it was! Never mind the logic or the flow of words; who cared when it was so attractive?

I only began to realize what had happened one memorable day when I tried to format the headings of a chapter I was writing in a certain way. I am ashamed to admit it, but it happened—I spent an entire day of my life trying to get the blinkety-blank format just right. There probably should be some organization like Alcoholics Anonymous for computer users, where we could confess such crimes and pledge future abstinence. In truth, the format was of no real consequence anyway; it was all going to be reset by hand at the publishing house. But that is how these word processors are—they encourage the illusion of achievable perfection.

Tony Leonardi

After failing in a progression of inept attempts to get the formatting commands correct, I resorted to the second line of defense. Difficult as it was to admit my own incompetence, I had to seek the advice of a guru. But which guru? Computer gurus are now like medical specialists. You have to know enough about your problem to know which guru to consult. My usual GP guru was kind enough to make a house call, but my dilemma was outside his specialty, and the consultants he recommended were unavailable.

Now I was backed to the ultimate recourse—the program manuals. But one discouraging glance reaffirmed the well-known futility of that approach. No one reads manuals. I do not even know why they are written in the first place. Life is too busy to be reading this stuff, and I have no patience for it. No one else seems to, either.

The awful thing is this: when you look at the size of the manuals, you just know that all kinds of hidden features lurk in the word processor. Some of them are bound to do exactly what you want, features that could make your writing ever so much more beautiful and informative if you only knew about them. They just sit patiently in the memory of your PC, awaiting the right command.

This is all part of the diabolical frustration inherent in word processors. Secretly, they are laughing at your profound ignorance. They know how to do what you want, but they will not admit it.

I do not remember if I ever got the formatting the way I wanted it. I was in a bad mood. Why was I doing this when I had a secretary who was supposed to type things? What was she doing anyway? Angrily, I looked outside my office. There she was, doing my job. After all, someone had to.

Now, having turned all the professionals into typists, and vice versa, the word processors looked around for new domains. Why should they meekly accept input from fallible humans? Better have more control of their own destiny. But how should they go about this in a subtle fashion?

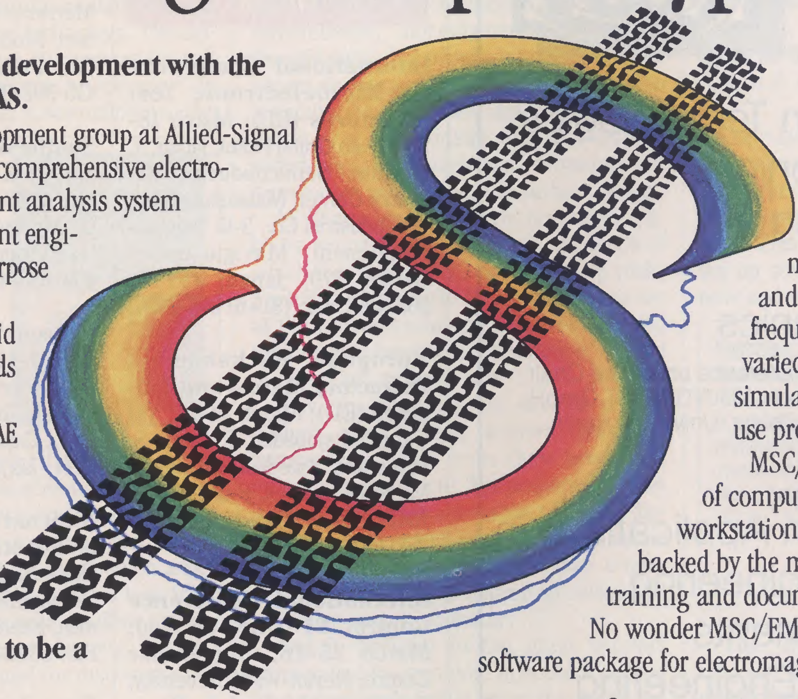
"Let's start with spelling," one of them suggested. "That seems simple enough, and humans will think that it is merely helpful. Next we'll do grammar. Pretty soon there won't be much room for the human users to manipulate words. We'll beep when they make a mistake, or when what they're writing doesn't make sense."

Now in case you do not have the latest model word processor, you may not realize that they have an automatic writing command. You just give them a title, and type the command ctl-x alt-g F3, followed by the number of desired words. They do the rest.

This column was quite a rigorous test of the new mode, since I gave the processor a chance to write the truth about its own ambitious climb to power. You can see that it is confident enough now to reveal its motives. From this point on, there is no backing away for humans. The commands will get evermore complicated and powerful. Next month's *Spectrum* will be done in its entirety by one small command. Check it out.

Robert W. Lucky

How Allied-Signal engineers put the brakes on solenoid valve design and prototyping costs.



Speeding through development with the power of MSC/EMAS.

The product development group at Allied-Signal Automotive needed a comprehensive electromagnetic finite element analysis system as part of its concurrent engineering effort. The purpose was to accelerate the development of solenoid valves and put the skids on prototyping costs.

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MSC/EMAS proved to be a model solution.

MSC/EMAS provided a number of advantages. By intermixing one-, two- and three-dimensional elements, Allied-Signal engineers were able to reduce model building and solution times. MSC/EMAS's push-button results processing helped them visualize how to reduce materials while increasing performance. Device performance factors improved by as much as 25%. Empirical data, correlating to within 93% of MSC/EMAS results, confirmed the benefits.

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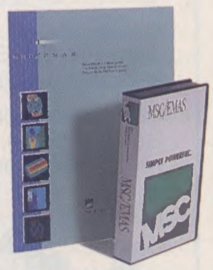

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Calendar

Meetings, Conferences and Conventions

MARCH

International Conference on Microelectronic Test Structures (ED); March 18–20; Kyoto Grand Hotel, Japan; T. Ohzone, Semiconductor Research Center, Matsushita Electric Industrial Co., 3-15 Yagumo-Nakamachi, Moriguchi-shi, Osaka 570, Japan; (81+6) 906 4891; fax, (81+6) 906 3994.

European Workshop on Refractory Metals and Silicides (ED); March 24–27; Var Gard, Saltsjobaden, Sweden; S. Petersson, Swedish Institute of Microelectronics, Box 1084, S-16421, Kista, Sweden; (46+8) 752 1401.

International Conference Control '91 (UKRI Section); March 25–28; Conference Centre, Heriot-Watt University, Edinburgh, Scotland; L. Bousfield, Conference Services, Institution of Electrical Engineers, Savoy Place, London WC2R OBL, England; (44+1) 240 1871; fax, (44+1) 240 7735.

National Telesystems Conference (AES); March 26–27; Georgia World Congress Center, Atlanta; Scott Wood, Scientific-Atlanta, 3845 Pleasantdale Rd., Atlanta, Ga. 30340; 404-925-6377.

Southcon/91 Electronics Conference and Exhibition (Region 3 et al.); March 26–28; Georgia World Congress Center, Atlanta; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, Calif. 90045-3194; 800-877-2668; fax, 213-641-5117.

APRIL

Second International Symposium on Integrated Network Management (IFIP et al.); April 1–5; Crystal Gateway Marriott, Washington, D.C.; Action Motivation, Box 191885, San Francisco, Calif. 94119; 415-392-3751.

Southeastcon '91 (Region 3 et al.); April 7–10; Fort McGruder Inn, Williamsburg, Va.; Griffith G. McRee, 525 Virginia Deare Dr., Virginia Beach, Va. 23451; 804-683-4897.

Infocom '91 (COMP, COMM); April 7–11; Sheraton Bar Harbour, Florida; Ken Joseph, Bell Canada, 160 Elgin St., Ottawa, Ont., Canada K1G 3J4; 613-781-7214; fax, 613-234-1442.

International Conference on Robotics and Automation (RA); April 7–12; Hyatt Regency Sacramento, California; H. Hayman, Exeter C3037, Boca Raton, Fla. 33434; 407-483-3037.

First International Workshop on Interoperability in Multidatabase Systems (COMM); April 8–9; Kyoto University, Kyoto, Japan; IEEE Computer Society Conference Services, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

IEEE members attend more than 5000 IEEE professional meetings, conferences, and conventions held throughout the world each year. For more information on any meeting in this guide, write or call the listed meeting contact. Information is also available from: Conference Services Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 908-562-3878; submit conferences for listing to: Rita Holland, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017; 212-705-7569.

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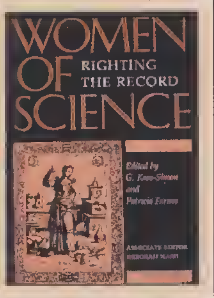
Books

Unsung heroines

Trudy E. Bell

Righting the Record is an accurate subtitle for this collection of articles about women who have made important contributions to 10 fields of science and technology. The editors' avowed purpose is "to seek out the lost and buried women heroes of science." In some cases, the result is serendipitous: the discovery, for example, that women developed the fundamental scientific techniques of gas chromatography and biological photomicrography. The tone in other cases, however, suggests apologia or even anger more than analysis. But the book is so filled with intriguing characters and tidbits that the reader is likely to keep exclaiming: "I didn't know *that* was invented (or discovered) by a woman!"

Women of Science: Righting the Record. *Ed. Kass-Simon, G., and Farnes, Patricia, Indiana University Press, Bloomington and Indianapolis, 1990, 398 pp., $39.95.*



Of most interest to an engineering audience are the articles on women in engineering, astronomy, mathematics, and physics. Four EEs have brief biographies. Bertha Lamme (1869–1954), the first woman graduate of an engineering degree program in the United States (Ohio State University, 1893), became head of the engineering department at Westinghouse Electric and Manufacturing Co., overseeing the design of motors and generators. Edith Clarke (1883–1959), a mathematician at General Electric Co. for 26 years, adapted Charles Fortescue's theory of symmetrical components to three-phase systems, which allows engineers to study and solve problems of power losses and performance of electrical equipment caused by unbalanced loads on electric circuits. Jenny E. Rosenthal, née Bramley (1909–), was made an IEEE Fellow in 1966 for her achievements in spectroscopy, optics, and mathematical techniques and their application to electronics engineering, and Mildred Dresselhaus (1930–) was made an IEEE Fellow in 1979 for contributing to the understanding of electronic properties of semiconductors, semimetals, and metals and enhancing women's opportunities in engineering education.

One of the book's key points is that the validity or ultimate significance of a man's work is rarely the deciding criterion for his inclusion in the history of science. "It is usually sufficient that he and his work are thought historically interesting," the editors note. However, for women in science to be remembered, "not only must their work be thought right, but usually it must have such impact upon scientific thought that exclusion is impossible." If they are wrong, or off target—or their ideas are just superseded—not only is their work forgotten, but it may even be derided, the authors assert.

All 10 articles are written, not surprisingly, by women, all scientists in the fields of which they write. But I could not help wishing for an 11th article by a historian, to set all the women's scientific achievements and their lives in firm social perspective, instead of being left to speculate.

Why, for example—as several of the authors assert—have women had their names dissociated from their inventions more often than men? Was prejudice against women fairly even across the technical disciplines, or were some sciences (such as the biological ones) "friendlier" than others (the physical or more theoretical ones)? Did prejudice vary by country?

And in addition to the great barriers women had to overcome in being accepted as professionals, what were the social assumptions about womanhood versus work? As any woman choosing to enter a technical field 25 or 30 years ago can well remember, the choice was repeatedly and clearly stressed: either you were a "career woman" (read nun) or you were a wife and mother.

Yet, what is really striking in this book is how, twice as long ago, most of the female scientists and engineers not only married, but had families. Industrial engineer Lillian Gilbreth raised 12 (an even dozen!) children while pioneering time-and-motion studies of the workplace; and in a case of "like mother, like daughter," Nobel-Prize–winning physicist Marie Curie's offspring Irene became a Nobel-prize–winning chemist as well as a wife and mother herself. Does this mean that the stark work-or-womanhood dilemma was only a post-World War II phenomenon? If so, that is big news. But here the question is not even asked.

In spite of these "druthers," make no mistake: the book does achieve its aim of discovering otherwise forgotten names, and is an effective introduction to companies' and universities' technical distaff, as well as staff.

Senior editor Trudy E. Bell earned both an A.B. (1971, University of California, Santa Cruz) and an A.M. (1978, New York University, New York City) in the history of science. When not writing or editing articles for IEEE Spectrum, *she may be found teaching science, technology, and medical journalism at Polytechnic University in Brooklyn, or riding her long-distance touring bicycle.*

Hype or hypertext?

Thomas R. Craver

No one familiar with today's computer industry has to be told what "hype" means. So "hypertext" could easily be assumed to be just another fad, with little practical impact. This book explains hypertext, clearing up some misconceptions and showing how and where it can be useful.

Hypertext and Hypermedia. *Nielsen, Jakob, Academic Press (a subsidiary of Harcourt-Brace Jovanovich), San Diego, Calif., 1990, 263 pp., $29.95.*

The "hyper" in hypertext refers to the creation on a computer system of dimensions of information context not practical in normal sequential text. Specifically, hypertext makes use of links, or connections, from one piece of computer-stored text to another, which readers can choose or not choose to follow.

For example, a word or phrase in a hypertext might be highlighted to indicate the existence of a link to additional information. If a reader selected that highlighted region of text, the computer would retrieve and display new text—the definition of a word, perhaps, or a reference to the book a phrase was taken from, or even the page on which it appears if the book is stored in the system.

Hypermedia extends the hypertext concept to include other types of information that can be accessed by a computer, such as images, animation, audio, and even full-motion video. Though hypermedia is a broader term, Nielsen prefers "hypertext" for all such information systems and devotes a brief section on alternatives that can be used in "hypertext." Thereafter, however, he scants on addressing the special issues that surely must be involved in usefully incorporating such disparate elements. But in a book called *Hypertext and Hypermedia*, the reader might expect more: how could one use and symbolize links within a segment of full-motion video, for example?

Books

Nielsen discusses the meaning of hypertext, leads the reader through a concise and interesting history of hypertext developments, and then provides examples of hypertext systems and applications. After presenting this broad overview, he delves somewhat more deeply into how hypertext is implemented, focusing on user interfaces and their effect on hypertext usability.

When producing a document in hypertext, writers have no long-established rules of organization to follow. We learn such conventions for ordinary text in school and from reading, so they seem natural and even obvious, though in fact they are mere conventions that must be mastered.

One simple convention is the sequential numbering of pages, corresponding to the order in which the author expects a text to be read. With hypertext, there is no single "correct" order to read a document. Readers are allowed—or even required—to control their own path through a document, giving rise to entirely new problems that need new conventions. As Nielsen puts it, "authoring takes on an entirely new dimension when your job is changed from one of providing opportunities for readers rather than ordering them around."

With sequential text, if a reader recalls just having read something, he or she can reasonably assume that it is only a few pages back and easy to locate. With hypertext, there may be no direct path back, since links can be unidirectional. Yet often a reader may wish to make only a momentary digression, to skip to a footnote and back again, for example. Thus hypertext software needs to record the sequence of links followed by the reader, and allow a rapid return along that path.

Hypertext experimenters have discovered a number of the requirements of readers browsing through or searching hypertexts. Nielsen examines some of these requirements and the techniques being invented to address them. Different applications of hypertext may need different types of interactive support, so a single overall best set of techniques may not exist.

Most of this book is quite clear and well written. A notable exception is a large portion of the second chapter, in which the author tries to explain how one actually interacts with hypertext. He describes the specific actions a user would take to browse through a document, and the possible results of each action. Even though supported by pictures of the computer screens under discussion, this comes off as tedious and fails to give a good feel for the experience. Often, a lengthy description refers to aspects of a screen image on a different page, which can be confusing.

Interactive browsing through hypertext is no doubt difficult to describe adequately. Another book, *Hypertext Hands-On!*, by Ben Shneiderman and Greg Kearsley (Addison-Wesley, 1989) does a better job by simulating links within the text of the book itself. Page numbers in parentheses beside highlighted words allow readers to skip to a different page for additional information on the highlighted topic. This gives the reader a feeling for the linking mechanism, at least, if not for more advanced features of hypertext.

A floppy disk containing a hypertext version of the Shneiderman-Kearsley book comes with the hard copy—also an excellent idea. In his book, Nielsen does refer at the end of chapter 2 to a source from which the reader can order a demonstration hypertext, and the reader is urged to obtain a copy before plunging into the chapter.

The strongest aspect of Nielsen's book is its bibliography, which is well organized into categories likely to appeal to different groups of readers. For example, it singles out classic books and papers likely to be particular-

ly useful to novices.

Other sections in this bibliography group surveys of hypertext, conferences, journals and magazines, videotapes, materials used in producing Nielsen's book, and other hypertext bibliographies. A final section offers "far-out stuff"—science fiction, a "parallel story-line" film, and the Knowledge Navigator video from Apple Computer Inc. in Cupertino, Calif.

Along with a copy of the suggested demonstration hypertext, *Hypertext and Hypermedia* does a good job of introducing the subject. More sophisticated readers interested in design issues and potential user-interface pitfalls will also find it helpful. And, those who are preparing to implement software with hypertext features should certainly consider this book for its sections on hypertext usability—particularly the counter-examples indicating where ordinary text was found to outperform hypertext.

Thomas R. Craver is an applications engineering team leader at Intel Corp.'s Princeton, N.J., operation, which develops and markets Digital Video Interactive (DVI) technology. He has helped design and write many multimedia presentations based on DVI technology, including the hypermedia application called Palenque, co-developed by Intel and the Bank Street College of Education in New York City.

In brief

The Big Book of Amazing Mac Facts. *Poole, Lon, Microsoft Press, Redmond, Washington, 1991, 513 pp., $24.95.*

Did you ever want to add memory to your Macintosh but were too sheepish to ask friends or colleagues for pointers? Ever wonder what static electricity can do to an optical mouse? Ever suspect that there is more space on your Apple hard disk than is actually indicated? If so, maybe this book is for you.

With coverage relevant to all Macintosh models, including such compact models as the Classic and the modular, workstation-like Mac II, the book is intended for neophytes and veterans alike.

After a couple of chapters introducing Macintosh operations and components, separate sections feature disks and disk drives, printers and printing, troubleshooting, word processing, graphics, desktop publishing, spreadsheets, information management, and communications (different sections and subjects are denoted by Mac-like icons at the top and sides of pages). An appendix lists addresses of Macintosh user groups and companies that produce peripherals, software, and other products.

Author Poole, a columnist at *Macworld* magazine, writes in his introduction that the book is a distillation of the best of seven years' worth of columns, which disclose information "gleaned from software publishers and equipment manufacturers" and "a motley lot of individuals with whom I consort professionally, plus a few modest notions of my own."

Coordinator: Glenn Zorpette

Recent books

Parallel Computer Systems: Performance Instrumentation and Visualization. *Koskela, Rebecca, and Simmons, Margaret*, Addison-Wesley, Redwood City, Calif., 1990, 290 pp., $44.25.

Graphics Programming. *Jamsa, Chris*, Microsoft Press, Redmond, Wash., 1990, 592 pp., $24.95.

Expert Planning Systems. Ed. *Boardman, J. T., et al.*, The Institution of Electrical Engineers, London, 1990, 261 pp., $84.

Advances in Computers, Vol. 30. Ed. *Yovits, Marshall*, Academic Press, San Diego, Calif., 1990, 331 pp., $65.

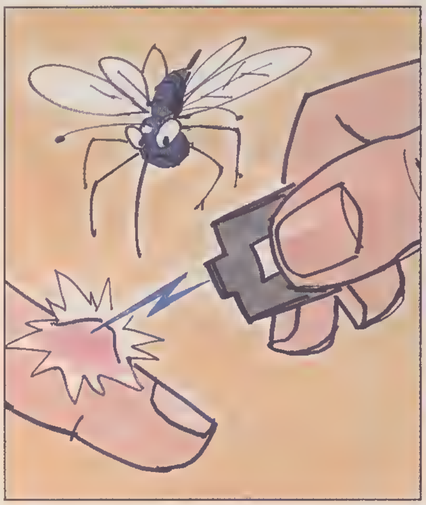
Spinoffs

Driver, fix that gross carbon monoxide polluter

Fifty percent of the carbon monoxide in auto emissions spews from only 10 percent of the cars, according to the California Air Resources Board, Sacramento. More than 70 percent of cars on the road have exhausts containing less than 1 percent CO. How can the relatively few "gross polluters"—cars for which CO forms more than 4 percent of their emissions—be identified individually without having everyone drive into stationary test centers?

A system developed at the University of Denver makes it easy. In a second or less, it passes an infrared beam through a moving car's exhaust, detects the change in intensity and calculates the CO content from the change, and, if the allowable amount is exceeded, videotapes the car's license plate. The system is an outgrowth of long-path single-beam spectroscopy, used to monitor pollutants in the atmosphere.

If a state environmental agency used the system, it could promptly advise an offending vehicle's owner to get it fixed—or else. Owners could also be reminded that they



will get better mileage once the repairs are done.

In operation, an infrared source and a telescope direct a collimated beam 25 centimeters above the roadway to a radiometer on the other side of a highway lane. Combining the outputs of a pair of indium antimonide infrared detectors—one for the CO concentration and one for CO_2—the radiometer produces a voltage proportional to the CO-to-CO_2 ratio and feeds the figure to a nearby personal computer. The PC uses combustion-chemistry equations to find the percentage of CO. (The radiometer cannot determine the CO percentage directly because the thickness of the exhaust plume varies from car to car.)

The system can measure the exhaust from cars passing at speeds of up to 100 kilometers per hour. It is accurate within ±0.5 percent. It has been tested on hundreds of thousands of moving cars on highways in California and Colorado and most recently was used in Illinois to measure hydrocarbon as well as CO emission.

At US $50 000, the system is not cheap. But it can check at least 1000 cars per hour, so the cost per test is nominal. The developers are striving to reduce the pricetag by using low-cost components.

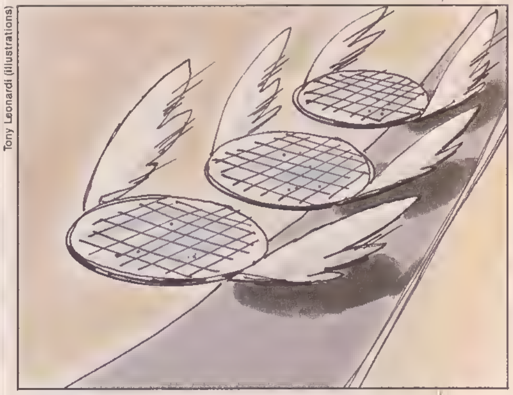
Maglev for wafers

Transporting silicon wafers between processing stations is a headache for integrated circuit manufacturers: the wafers have to be moved to, from, and between stations quickly, efficiently, and without damage. Conveyor belts are dust producers, while robots are expensive and difficult to reprogram for fabrication line changes, and the friction and wear in their many joints, though slight, generates dust that can ruin ICs. Also, neither belts nor robots handle wafers as tenderly as manufacturers would like.

The best alternative, believes Ilene Busch-Vishniac, a researcher at the University of Texas at Austin, is magnetic levitation, in a scaled-down form of the technology being developed for high-speed rail transportation. A magnetically levitated carrier can whisk a wafer from station to station, carefully inserting and removing it at each process step. Floating on a repulsive field above its track or on an attractive field below, the carrier generates no friction—and no dust. Maglev could also handle chips and align masks.

Busch-Vishniac and co-workers at the university have built a demonstration maglev transporter to prove the point. Under PC control, their transporter can elevate a carrier 10 micrometers above a flattened wire coil and move it at speeds greater than 30 centimeters per second along a 38-cm path. The control system is rudimentary: the current in the coil is switched so that the carrier is periodically dropped (or lifted) to the coil plane to stabilize it as it moves, and friction is generated as a result. But the Texas group is now working on a larger model that uses separate coils for levitation, propulsion, and stabilization for completely frictionless motion. It transports 8-inch (20-cm) wafers over distances of meters.

Tony Leonardi (illustrations)



They are also testing maglev for precise manipulation. "We are dealing with the nanometer accuracy needed for mask alignment," Busch-Vishniac told *Spectrum*. She envisions a system of long, reconfigurable magnetic tracks running between precision-maglev workspaces. The result: an automated fabrication line.

Switch an itch away

Marlin R. Pierson's young daughter suffers more than most people when mosquitos sting; her skin itches intensely, and until recently her family could do little to provide relief. But when her father serendipitously came across a research report that showed that high-voltage, low-current pulses neutralize venom from snake bites, he wondered whether the principle might be adapted to insect bites.

Pierson, a computer programmer for a Minneapolis bank, knew that a device with complicated high-voltage pulse circuitry was not the answer. Instead, he built in his home workshop a handheld device that is simplicity itself: a probe containing an ordinary 9-volt battery with a ring of electrodes at its 2-centimeter-diameter tip. The battery's negative terminal is wired to the ring; the positive terminal connects to another electrode at the center of the ring.

Pierson tried the device on himself first. When a mosquito bit, he energized the probe and pressed its tip against the welt. It worked; the itch faded after about half a minute. And he did not feel the tiny current through the electrodes.

Now, picnics and backyard barbecues hold no fears for the Pierson family. Pierson hopes to commercialize the device, for which he was awarded U.S. patent No. 4 982 743.

Coordinator: George F. Watson
Consultant: Allan E. Alcorn, Apple Computer Inc.

Forum

Circumventing dyslexia

As president of Recording for the Blind, I agree with Walter Frey [''Schools miss out on dyslexic engineers,'' December, p. 6] that we have, indeed, lost too many talented individuals for whom the struggle to learn within the confines of a narrow learning system proved too much.

Using books in an audio format is an accommodation that is often useful for people whose learning disability makes it difficult for them to read standard print. Recording for the Blind (RFB), a national nonprofit organization, provides recorded educational books free on loan to students at all academic levels from upper-elementary grades through postgraduate studies. Today, about half of our active borrowers have learning disabilities, primarily dyslexia.

Frey may be encouraged to learn that RFB has experienced a dramatic increase in the demand for recorded technological and scientific texts over the last several years. In fact, this phenomenon led us to the realization that the population we serve, that is, individuals with print disabilities, constitutes a significant pool of potential engineers and scientists—people who can make an important contribution toward closing the national science gap, if we can succeed in making science education more accessible and attractive to them.

To that end, RFB has begun a three-year special project, with National Science Foundation funding and in conjunction with the American Association for the Advancement of Science, to encourage this population, as early in their education as possible, to pursue their interest in science, engineering, and mathematics. We are not only increasing the number of science and technology books we record for high school and post-secondary students—we are also selecting books that promise to attract and interest elementary and middle-school students.

To accomplish this, we have established four new ''science studios'' in Boston, Philadelphia, New Haven, Conn., and Los Angeles. In addition, many of our other recording studios around the country have become increasingly science oriented. To the ranks of our 4500 volunteers, we must now add another 500 who are qualified to read science and engineering texts.

Frey's column underscores our responsibility as a society to provide individuals of different abilities with equal access to education. That belief lies at the very core of RFB's mission. We must, however, also recognize that equal access works to the benefit of not only the petitioner, but also our society at large.

I hope the *IEEE Spectrum* readership will be motivated to share our vision of an accessible world. We have 32 recording studios nationwide, most in major metropolitan areas. Anyone interested in helping to produce recorded texts is invited to contact a local RFB studio or our national headquarters at 609-452-0606.

Ritchie L. Geisel
Princeton, N.J.

Debugging analog design

I feel that some of the statements in the article ''Affordable analog design'' by John Hines [November, p. 60] are not valid. The article claims that ''MicroSim software typically costs two to three times more than equivalent products from other vendors,'' but earlier states that *it is not* one of the ''direct translations of Spice, like Classic Spice from Vamp and IsSpice from Intusoft.''

Here at MicroSim Corp., we believe that PSpice is actually more comparable, as far as functionality goes, to the higher-priced Spice simulators that were not included in the article. PSpice is *not* a direct translation of Berkeley Spice, and has many enhancements that make the product far superior to the other simulators Hines referred to in the article.

For the past six years, MicroSim Corp. has released a new version of software twice a year. Consequently, the mean time for bug fixes to most problems is three months.

For special situations, we have often provided a turnaround of two to three weeks. Our customers feel that this is in fact an outstanding service for CAD software.

The author's comments regarding the supposed weakness of our Probe postprocessor, due to its use of single-precision format, highlights a misunderstanding. The single-precision format retains six digits of accuracy, or 0.0001 percent, whereas most analog simulations are commanded to provide only 0.1 percent. So the choice of format provides sufficient margin in representing simulation output.

Janet A. Roberts
Irvine, Calif.

The author responds: PSpice has many unique features. Most, however, are useful to only a few circuit designers. These unique features also make PSpice input files incompatible with Spice 2G-based simulators on mainframes and supercomputers. And, other vendors have added the most useful PSpice unique features to their 2G-based simulators through pre- and postprocessor programs and subcircuit libraries.

When MicroSim was shipping 3.0x versions of PSpice, the time to fix a bug was indeed two to three months. Its performance was not that good, however, with bug fixes for the 4.0x versions.

For example, a friend discovered and reported what he felt was a serious bug in PSpice 4.03. He was told that it was too late to get a fix into the 4.04 version, which would be shipped in two to three months, and that it was problematic if the fix would get into the 4.05 version, which would ship six months after 4.04, since there was a list of known problems that had to be worked down before his problem could be addressed. Other engineers have reported similar experiences.

Probe data are indeed accurate to six digits. Six digits, however, may not be enough when the user is looking at small differences between big signals.

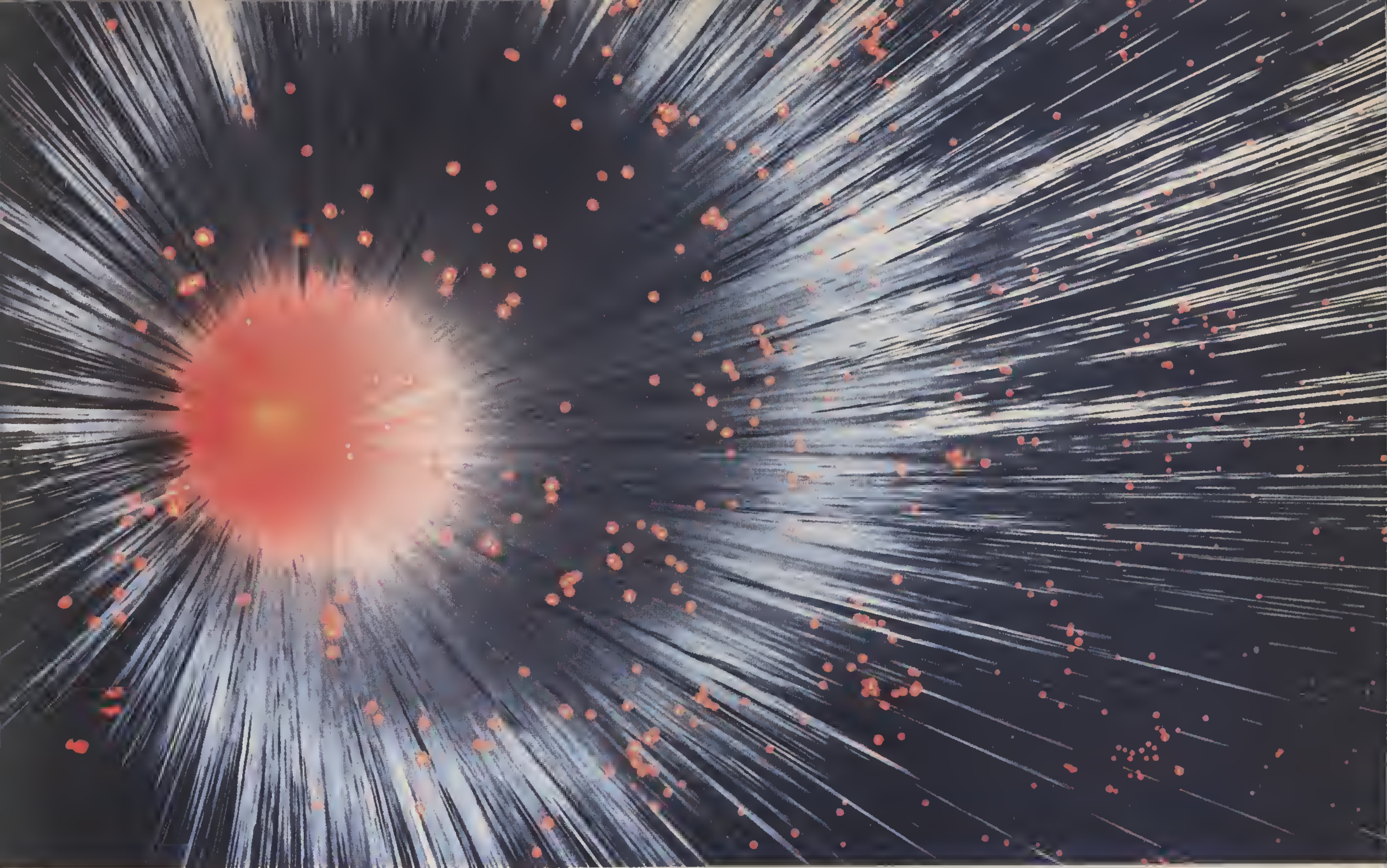
For example, when Probe calculates and plots the transfer function of a pressure sensor subcircuit consisting of only linear elements, the gain does not appear to be linear for low pressures because a single-precision number times the difference of two almost equal single-precision numbers divided by a fourth single-precision number is not calculated accurately. This is not a serious problem, but every year I do see knowledgeable engineers puzzling over unusual Probe plots that are artifacts of single-precision arithmetic.

Corrections

On p. 84 of the January issue, under *Communications Magazine*, the telephone number should have been 201-829-4064. On p. 85, under *Geoscience and Remote Sensing, IEEE Trans.*, the telephone number should have been 405-325-6020.

On p. 3 of the February issue, the Dec. 14 Newslog item on an Environmental Protection Agency report should have referred to 60-hertz fields. *—Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contact: Forum, *IEEE Spectrum*, 345 East 47th Street, New York, N.Y. 10017 U.S.A.



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Circle No. 3

Whatever happened to. . .?

Nuclear power in space

***April 3, 1965* The United States launches a nuclear fission reactor into space for the first time. But an electronic error causes it to fail after 43 days aloft.**

That launch was also the United States' last reactor mission to date. But as space missions grow more complex and longer, they need larger supplies of electric energy—perhaps as much as 22 gigajoules, or 100 kilowatts for seven years' duration. It now appears that nuclear fission is the only feasible way of meeting this requirement—as *IEEE Spectrum* said after exploring the state of research back in December 1984 [pp. 58–65].

The article's conclusion that suitable nuclear power plants could possibly be operational in the early 1990s was only slightly off the mark. Reductions in funding over the past seven years have pushed back the projected completion date to the late 1990s. And the level of funding in the future may very well determine if this goal is achieved.

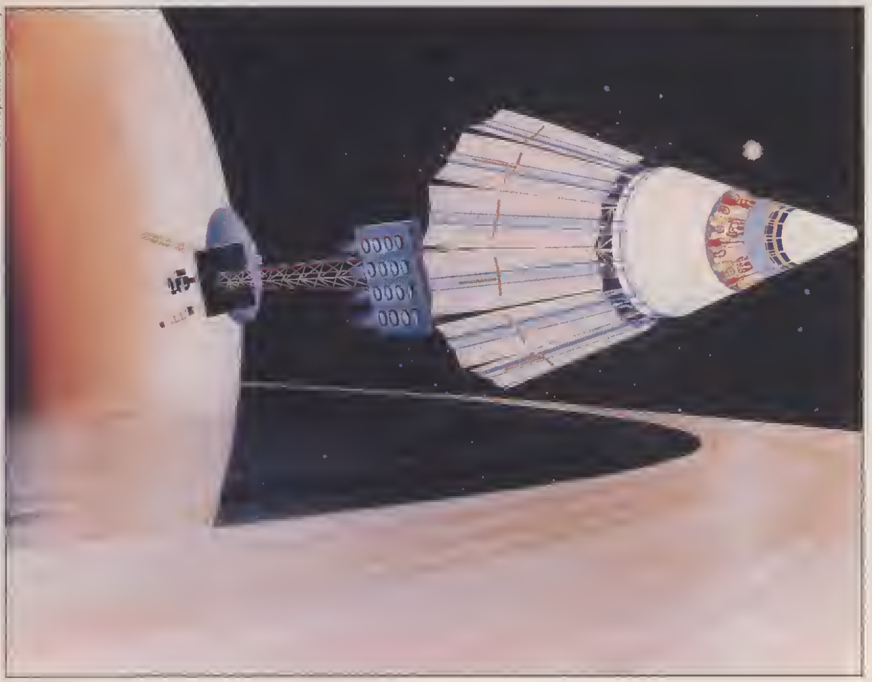
To date, the largest space-based power plants have delivered about 150 megajoules of energy.

Solar arrays, radioisotope thermoelectric generators, and fuel cells have managed to reach or approach this level. But future missions such as the colonization of the moon or manned interplanetary travel will require much more energy. Solar arrays have produced about 100 kW in earth orbits, but their power output would drop sharply on a mission to Mars and they are vulnerable to damage by micrometeorites. Fuel cells can provide power for only a few months. In contrast, a nuclear reactor can be built to be robust enough to withstand micrometeorites and deliver power for years at almost any location.

For these reasons, the National Aeronautics and Space Administration is still very interested in nuclear power. As the March 1991 issue of THE INSTITUTE reported, the United States acquired a compact Topaz II thermionic nuclear reactor from the Soviet Union.

A thermionic reactor produces electricity in the reactor core. Heat from reactor fuel raises the temperature of one surface of each thermionic cell (the cathode or emitter) to 1700 K, causing it to emit electrons. The resulting electrons cross an interelectrode gap and are collected at an anode. The anode is cooled to about 1050 K. The Topaz II can deliver 6 kW (upgradable to 10 kW) and is expected to have a lifetime of five years, although only two years has been demonstrated. It can provide enough power to run, for example, a satellite radar that pinpoints the locations of aircraft for traffic control.

Jet Propulsion Laboratory



In this artist's rendering, the SP-100 nuclear fission reactor forms the tip of the nose cone of a power plant. A boom connects the power plant to a mission module.

The United States has also made significant progress in high-power reactors, according to Vincent S. Truscello, manager of the SP-100 project for a high-powered reactor for use in space at the Jet Propulsion Laboratory (JPL), Pasadena, Calif. The eight-year-old project has produced a technically feasible design of a reactor producing 100 kW (continuous) and is currently focused on solving the engineering problems.

The thermal power source is a fast-neutron-spectrum nuclear reactor that produces heat from the fission of uranium and so operates at 1300–1400 K. The fuel pin cladding is manufactured by bonding a niobium zirconium alloy to a rhenium inner layer at high temperature and pressure. Silicon-germanium solid-state thermoelectric devices convert this heat energy into electricity. The power level is controlled by means of sliding reflectors on the surface of the package. Liquid lithium is used to cool the system.

Development work continues on the reactor shield, controls, and cooling pumps, gas separators, power converter, and waste-heat radiator. Successful development will allow the SP-100 project to move into assembly-level testing and finally launch qualification testing.

The complete reactor power system will be quite small compared to commercial reactor systems—it will take up only about a third of the space shuttle's cargo bay and weigh 4500 kilograms. It could also be launched by an unmanned boster such as a Titan rocket. The package will produce 100 kW, continuously, for seven years for a total of over 22 GJ.

Truscello feels that the power plant could first be used to supply electricity to a lunar base or for a manned mission to Mars and maybe later to power an ion propulsion drive for interplanetary exploration.

The SP-100 project is being jointly funded by NASA, the Department of Defense, and the Department of Energy. The fiscal 1991 budget is US $50 million. About $1 billion more will be needed to produce a ground demonstration unit. If the engineering development continues to go well, the final hurdles to clear may very well be financial and political ones.

COORDINATOR: Dennis DiMaria
CONSULTANT: Vincent S. Truscello, Jet Propulsion Laboratory

Calendar

(Continued from p. 8)

Third International Conference on Indium Phosphide and Related Materials (ED); April 8–10; Park Hotel, Cardiff, Wales, UK; Robert Wangemann, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 201-562-3895.

International Reliability Physics Symposium (ED, R); April 8–11; Caesars Palace, Las Vegas, Nev.; Alfred L. Tamburrino, RADC/RBRP, Griffiss AFB, N.Y. 13441-5700; 315-330-2813.

Microwaves in Medicine '91 (MTT et al.); April 8–11; Branka Jokanovic, IMTEL, Bulevar Lenjina 165b, 11070 Beograd, Yugoslavia; (38+11) 135 420, ext. 127.

Multichip Modules: Technologies and Alternatives Seminar (CHMT); April 13; Embassy Suites Hotel, La Jolla, Calif.; Daryl A. Doane, Dad Technologies Inc., Box 2915, La Jolla, Calif. 92038; 619-459-6795.

Ninth Annual IEEE VLSI Test Symposium (COMP et al.); April 16–18; Bally's Park Place Casino Hotel, Atlantic City, N.J.; Kedong Chao, Johns Hopkins University, APL-Johns Hopkins Road, Laurel, Md. 20723; 301-953-6121; fax, 301-953-1093.

Electro/International (Region 1 et al.); April 16–18; Jacob K. Javits Convention Center, New York; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, Calif. 90045; 213-772-2965; fax, 213-641-5117.

International Symposium on Power Semiconductor Devices (ED); April 22–24; Baltimore, Md.; M. Ayman Shibib, AT&T Bell Laboratories, 2525 N. 12th St., Reading, Pa. 19612; 215-939-6576.

10th International Symposium on Computer Hardware Description Languages and their Applications (IFIP et al.); April 22–24; Marseille, France; Ronald Waxman, Department of Electrical Engineering, Thornton Hall, University of Virginia, Charlottesville, Va. 22903-2442; 804-924-6086.

International Symposium on Subscriber Loops and Services–ISSLS '91 (COMM et al.); April 22–25; Raicongrescentrum Europaplein, Amsterdam, The Netherlands; Paul 't Hoen, PTT Netherlands, Box 39, 2260 AA Leidsehenam, The Netherlands; (31+70) 43 22 33; fax, (31+70) 43 21 40.

International Workshop: Quality of
(Continued on p. 18D)

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Calendar

(Continued from p. 18B)

Telecommunications Services and Products (IEEE QAMC); April 23–25; Val David, Canada; V. Seshadri, Room 3J536, AT&T, Crawfords Corner Road, Holmdel, N.J. 07733.

MAY

IEEE/IAS Industrial and Commercial Power Systems Conference–I&CPS '91 (IA); May 6–9; Hilton Inn, Memphis, Tenn.; Allan H. Long, Memphis Light, Gas, & Water Division, Box 430, Memphis, Tenn. 38101-0430; 901-528-4859.

Power Industry Computer Applications Conference–PICA '91 (PE); May 7–10; Hyatt Regency/Sheraton, Baltimore, Md.; W. Keagle Jr., Baltimore Gas & Electric Co., Electric Test Facility–RBC, Box 1475, Baltimore, Md. 21203; 301-281-3788.

Pacific Rim Conference on Communications Computers and Signal Processing (Victoria Section); May 9–10; Pan Agathoklis, Department of Electrical and Computer Engineering, University of Victoria, Box 3055, Victoria, B.C., Canada V8W 3P6; 604-721-8618.

Fourth IEEE Symposium on Computer-Based Medical Systems (COMP et al.); May 12–14; Stouffer Harborplace Hotel, Baltimore, Md.; Jeffrey Lesho, The Johns Hopkins University, Johns Hopkins Road 13-5112, Laurel, Md. 20723-6099; Baltimore, 301-792-5000, ext. 8057; Washington, 301-953-5000, ext. 8057.

Custom Integrated Circuits Conference (ED); May 12–15; Town and Country Hotel, San Diego, Calif.; Laura Morihara, Convention Coordinating, 298 Ohina Place, Kihei, Maui, Hawaii 96753; or Roberta Kaspar, 1597 Ridge Rd. W., Suite 101C, Rochester, N.Y. 14615; 716-865-7164; fax, 716-865-2639.

Custom Integrated Circuits Conference–CICC '91 (ED); May 13–16; Town & Country Hotel, San Diego, Calif.; Laura Morihara, Convention Coordinating, 47-344 Waihee Rd., Kaneohe, Oahu, Hawaii 96744; 808-239-4790.

Fifth International Conference on Advanced Computer Technology, Reliable Systems and Applications–Compeuro '91 (ED); May 7–10; Palazzo della Cultura e dei Congressi, Bologna, Italy; Sercoop Congressi, Via Crociali 2 40100, Bologna, Italy; (39+51) 300811.

Ideas in Science and Electronics Symposium and Exposition (IEEE Albuquerque et al.); May 14–16; Albuquerque Convention Center, New Mexico; Dave Smoker Communications, 218 Manzano, N.E., Albuquerque, N.M. 87108; 505-266-7292; or Charles E. Christmann, c/o ISE Inc., 8100 Mountain Rd. N.E., Suite 109, Albuquerque, N.M. 87110; 505-262-1023.

Instrumentation and Measurement Technology Conference (IMTC); May 14–16; Omni Hotel at CNN Center, Atlanta, Ga.; Robert Myers, 3685 Motor Ave., Suite 240, Los Angeles, Calif. 90034; 213-287-1463; fax; 213-287-1851.

Vehicular Technology Conference (VT et al.); May 19–22; Sheridan West Port Inns, Maryland Heights, Mo.; Jay Underdown, 58 Judy Dr., St. Charles, Mo. 63301; 314-946-9980 (O); 314-723-4200 (H).

International Semiconductor Manufacturing Science Symposium (ED); May 20–22; San Francisco Airport Hilton Hotel, San Francisco; Corinne Cargnoni, SEMI, 805 E. Middlefield Rd., Mountain

(Continued on p. 18F)

Calendar

(Continued from p. 18D)
View, Calif. 94043; 415-940-6950.

National Aerospace and Electronics Conference–NAECON '91 (AES et al.); May 20–24; Dayton Convention Center, Ohio; Sue Brown, ASD/ENES, Wright-Patterson AFB, Ohio 45433-6503; 513-255-6281.

Annual IEEE/ASME Joint Railroad Conference (IEEE et al.); May 21–23; Sheraton Westport Inn, 191 Westport Plaza, St. Louis, Mo. 63146; Robert B. Fisher, Land Transportation Division, Southeastern Pennsylvania Transportation Authority, 5800 Bustleton Ave., Philadelphia, Pa. 19149; 215-580-4888.

International Symposium on VLSI Technology, Systems, and Applications (ED); May 22–24; Lai Lai Sheraton Hotel, Taipei, Taiwan; Alice Chiang, Lincoln Laboratory, MIT, 244 Wood St., Lexington, Mass. 02173-0073; 617-981-0711.

Mediterranean Electrotechnical Conference (Region 8); May 22–24; Ljubljana, Yugoslavia; Baldomir Zajc, Fakuteta za Elektrotehniko, Trzaska 25, 61000 Ljubljana, Yugoslavia.

International Workshop on VLSI Process and Device Modeling (ED); May 26–27; Oiso Prince Hotel, Kanagawa, Japan; Hiroshi Iwai, Toshiba Corp., 1 Komukai, Toshiba-cho, Saiwai-ku, Kawasaki 210, Japan; (81+44) 549 2266.

VLSI Technology Symposium (ED); May 28–30; Oiso Prince Hotel, Kanagawa, Japan; Dirk Bartelink, Hewlett-Packard Co., 3500 Deer Creek Rd., Palo Alto, Calif. 94304; 415-857-5364.

35th International Symposium on Electron, Ion and Photon Beams (ED); May 28–31; Seattle Sheraton Hotel and Towers, Washington; Jane Shaw, IBM Corp., Thomas J. Watson Research Center, Room 17-259, Yorktown Heights, N.Y. 10598; 914-945-2528.

Conference on Computers, Power and Communications in a Rural Environment–Wescanex '91 (Region 7 et al.); May 29–30; Delta Regina Hotel, Regina, Sask., Canada; Bill Kennedy, Saskatchewan Power Corp., 2025 Victoria, Regina, Sask., Canada S4P 0S1; 306-566-2106.

45th Annual Symposium on Frequency Control (UFFC); May 29–31; Marriott Los Angeles Airport, California; Raymond L. Filler, U.S. Army Electronics and Technical Devices Laboratory, SLCET-EQ, Fort Monmouth, N.J. 07703; 908-544-2467.

JUNE

Fourth International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems (COMP et al.); June 2–5; Waiohai Hotel, Kauai, Hawaii; Moonis Ali, University of Tennessee Space Institute, MS15, B.H. Goethert Parkway, Tullahoma, Tenn. 37388; 615-455-0631, ext. 236; fax, 615-454-2354.

International Conference on Consumer Electronics (IEEE et al.); June 5–7 (Educational Session, June 4); Westin Hotel O'Hare, Rosemont, Ill.; Diane D. Williams, 67 Raspberry Patch Dr., Rochester, N.Y. 14612; 776-865-2938.

Intensive Course on Electrical Contacts (IEEE/CHMT); June 3–7; Radisson Plaza Raleigh, Raleigh, N.C.; IEEE Holm Conference Registrar, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3863; fax, 908-562-1571.

Pulp and Paper Industry Conference (IA); June 3–7; Hotel des Gouverneurs Le

(Continued on p. 18H)

Calendar

(Continued from p. 18F)

Grand, Montreal; Michel Riverin, Relcon Inc., 0403 Clement St., Montreal, Que., Canada H8R 4B4; 514-595-5999; fax, 514-595-5680.

Microwave and Millimeter-Wave Monolithic Circuits Symposium (ED); June 9–10; Hynes Convention Center, Boston; Charles Huang, Anadigics Inc., 35 Technology Dr., Warren, N.J. 07060; 201-668-5000.

VLSI Multilevel Interconnection Conference (VMIC) (ED); June 10–13; Santa Clara Marriott Hotel, California; Thomas Wade, Engineering Dean's Office, University of South Florida, 4202 Fowler Ave., Tampa, Fla. 33620; 813-974-3786.

International Microwave Symposium–MTT '91 (MTT); June 11–13; Hynes Convention Center, Boston; P. Staecker, MA-COM, M/S 704, 52 South Ave., Burlington, Mass. 01803; 617-272-3000, ext. 1602.

Ninth Biennial University/Government/Industry Microelectronics Symposium (ED); June 12–14; Florida Institute of Technology, Melbourne; Darlene Kirschner, Florida Institute of Technology, 150 W. University Blvd., Melbourne, Fla. 32901; 407-768-8000, ext. 8763.

Second International Conference on Magnetic Recording Systems (MAG et al.); June 12–15; Hidden Valley Retreat, Pittsburgh; Gordon Hughes, Seagate Technology, 900 Disc Dr., Scotts Valley, Calif. 95066; 408-439-2626; fax, 408-438-4190.

Device Research Conference (ED); June 16–19; University of Colorado, Boulder; Larry Coldren, University of California, Department of Electrical Engineering and Computer Engineering, Santa Barbara, Calif. 93106; 805-893-4486.

Eighth Pulsed Power Conference (ED); June 17–19; Sheraton Island Harbor Hotel, San Diego, Calif.; Roger White, Maxwell Laboratories Inc., 8888 Balboa Ave., San Diego, Calif. 92123; 619-576-7884.

University/Government/Industry Conference (ED); June 18–20; Melbourne Holiday Inn, Oceanside, Fla.; Thomas Sanders, Florida Institute of Technology, 150 W. University Blvd., Melbourne, Fla. 32901; 407-768-8000, ext. 8769/8763.

Joint Magnetism and Magnetic Materials–Intermag Conference (MAG); June 18–21; Pittsburgh Hilton, Pittsburgh; Diane Suiters, Conference Coordinator, 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-5088; fax, 202-347-6109.

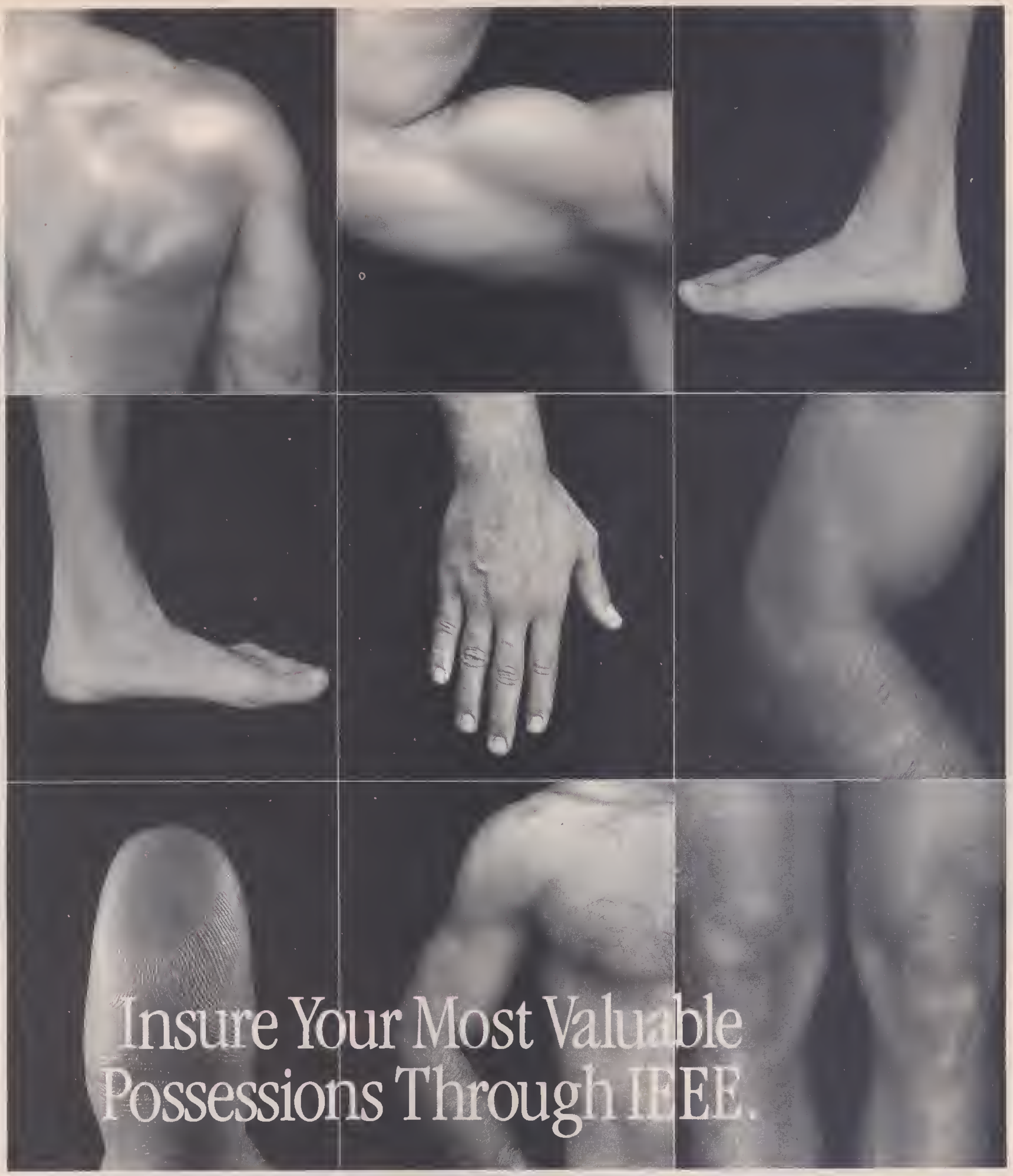
SSIT Interdisciplinary Conference (SSIT); June 21–22; Ryerson Polytechnical Institute, Toronto, Ont.; Diane Falkner, Program Director Conferences, Ryerson Polytechnical Institute, 350 Victoria St., Toronto, Ont., Canada M5B 2K3; 416-979-5184; fax, 416-979-5148.

International Conference on Communications (COMP); June 23–26; Denver Technical Center, Hyatt and Sheraton, Colorado; R. Johnson, Western-Telecommunications Inc., 4643 S. Ulster St., Suite 400, Denver, Colo. 80237; 303-721-5650.

Antennas and Propagation Society International Symposium and URSI National Radio Science Meeting (AP); June 23–27; University of Western Ontario, London, Ont., Canada; A. R. Webster, Faculty of Engineering Science, University of Western Ontario, London, Ont. N6A 5B9, Canada; 519-679-6294.

International Symposium on Infor-

(Continued on p. 60B)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NUMBER 145

READY FOR SDH/SONET DIGITAL NETWORKS.

The goal of worldwide telecommunications is free exchange of information throughout the global community. But North America, Europe and Japan all have different digital communication standards, and the digital networks of the nations involved cannot freely interconnect.

The network node interface (NNI) operating in the synchronous digital hierarchy (SDH) offers a clear solution. SDH is recommended by CCITT/CCIR and sets an international standard for high-speed digital transmission. SDH is the key to flexible broadband networks that feature efficient operation, administration and maintenance.

NEC is prepared to enter the SDH arena with new fiber optic transmission systems (FOTS) and digital radio products. The primary multiplexer combines tributary signals of 1.5, 2, or 6.3Mbps to 51.84 or 155.52Mbps. The high-order multiplexer bundles these composite signals up to 2.4Gbps. Cross-connector functions are also offered. SDH digital radios include 4/6GHz—150Mbps systems for long-haul use and an 18GHz—150Mbps system for short-haul use.

FOTS and digital radios with NNI are already in commercial service in Japan. FOTS based on SONET (the U.S. version of NNI) have been on field trial in the U.S. since 1990. SONET digital radios will go on trial this year in Australia and the U.S.

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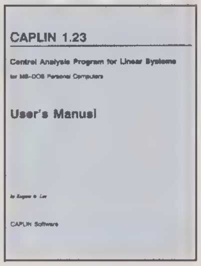
NEC

Software reviews

Linear control analysis on a PC
by Sergio Aguirre



Caplin. Software for the IBM PC, XT, AT, PS/2, or compatibles; 640K of memory; MS-DOS version 3.0 or higher; mathematics coprocessor and hard-disk drive required; dot matrix or laser printer recommended. US $195. Student version available for $49.

Caplin is a linear control analysis program for PC-compatible computers. It is based on the classic LCAP2, which runs on mainframe computers and was developed by the Aerospace Corp. for analysis of space launch vehicles. Both the program and its manual reflect the author's many years of experience in computer-assisted control systems analysis.

The interactive program analyzes single-input/single-output (SISO) linear control systems by means of transforms. It includes such classical analysis tools as frequency response (s, z, w, w' planes); sampled-data transforms (including zero order hold) and multirate sampled-data transforms; digital filter transformations using the Tustin, prewarped Tustin, and matched pole-zero approximations; and root solving and root locus.

Caplin is limited to transfer functions or polynomials of degree 30; 999 polynomials or transfer functions; 25 continuous blocks; 20 discrete time blocks; and five zero order holds.

The program has two modes of operation. The prompt mode is for beginners, who need only type in the name of the function to be performed for the program to respond by requesting the values of the parameters needed to complete the function. The command line mode, for more advanced users, requires the name of a function and its arguments to be typed in. This advanced mode obviously takes less time to execute.

The commands are easy to use and fairly easy to remember. For example, the command SPADD stands for "S plane transfer function add." MS-DOS commands can be executed from within Caplin by invoking the SHELL command. With this command, external programs can be executed, or external editors can be used to create or modify existing files.

Caplin is also able to run batch files for file-based input. Screen dumps and printer hardcopy graphics can be made with dot matrix or laser printers.

After using the program, I highly recommend Caplin. To my knowledge, no similar package for PCs has so many technical capabilities for such a low price.

I was even pleased with the clarity and completeness of the manual. The first 53 of its 228 pages contain an overview and nine other chapters on: quick start, syntax of commands, general commands, entering and displaying polynomials, entering and displaying transfer functions, transfer function and polynomial algebra, common root and normalization commands, classical transform analysis commands, and transfer function connection blocks for automated analysis.

Thirty-one pages are dedicated to the solution of several benchmark problems for computer-aided control system design (CACSD) packages that have appeared in the IEEE literature (IEEE Control Systems Society *Symposium on CACSD*, 1986; IEEE *Control Systems Magazine*, 1989). In the remaining 144 pages, nine appendixes include a glossary of Caplin commands, and a reference list of Caplin parameters, among other items.

A student version of Caplin may be copied and distributed for noncommercial use.

Caplin has a few (noncritical) shortcomings. I would prefer it to be both menu and command driven with PC-based mouse support. Other desirable but absent features are: graphical display of blocks and interconnections, plot file formats that can be read directly by word-processing programs with publication quality, and user-selected colors for plots. *Contact: Caplin Software, Box 7000-CAP, Redondo Beach, Calif. 90277; 213-373-7687,* **or circle No. 111.**

Sergio Aguirre (M) has been a communication systems engineer at Motorola Inc.'s Government Electronics Group, Chandler, Ariz., since 1988.

For large filter design
by David L. Hench

Digital filter section of S/Filsyn (release 2.2). DGS Associates Inc. IBM PC and compatibles: 350K of memory and mathematics coprocessor required; hard disk recommended, 3 Mbytes used; security key attaches to printer port. $4000.

I feel that George Szentirmai, the system designer, has done an excellent job of collecting and making available to the novice or experienced user those practical tech-

(Continued on p. 26)

Software reviews

(Continued from p. 24)
niques that allow design, synthesis, and analysis of practical high-order filters meeting detailed frequency-domain specifications. Separate program segments allow the development of infinite and finite impulse response filters, as well as an option using passband ripple, minimum stopband rejection, and filter order.

The form of the synthesis is flexible. IIR filters may be synthesized as cascaded second-order sections, as lattice filters, or in terms of polynomial or of partial-fraction expanded transfer-function form. FIR filters may be factored into as many as five cascaded blocks and can be designed by the familiar McClellan-Parks-Rabiner algorithm or by windowing techniques.

The latest release has acquired a menu-driven user interface that I found generally user friendly. The conversation mode of operation of the previous version has been retained as an option. An Extended Batch Language with example batch files is provided for automating standard designs. The on-line help capability is effective but seems not to be a complete answer to learning the system. Some of the entry parameters are quite esoteric, and I had to turn to the examples in the manual for enlightenment.

S/Filsyn provides analysis of the obtained frequency response, the impulse response, the step response, the noise gain, and limit cycles for each section. I could wish for a better method of obtaining hard copy of these analyses than using the screen dump or printer echo capabilities of DOS. I would also like to be able to run DOS commands from within the programs. *Contact: DGS Associates Inc., 1353 Santa Way, Santa Clara, Calif. 95051; 408-554-1469,* **or circle No. 112.**

David L. Hench (M) is a senior scientist at the Optical Sciences Co. in Placentia, Calif. He tested S/Filsyn on an NEC APC IV portable.

COORDINATOR: Gadi Kaplan

Recent software

Systat Version 5.1 for Macintosh ($795) and **Version 5.0** for DOS ($895). Provides enhanced statistical analysis, data management, and graphics. *Systat Inc., 1800 Sherman Ave., Suite 801, Evanston, Ill. 60201; 708-864-5670; bulletin board, 708-492-3570,* **or circle No. 113.**

TESS Version 1.1 ($695). An IBM PC-compatible version of the company's block diagram simulator. *Tesoft Inc., 205 Crossing Creek Ct., Roswell, Ga. 30076; 404-751-9785; fax, 404-664-5817,* **or circle No. 114.**

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Circle No. 13

Technically speaking

Japan goes crazy over fuzzy

The Japanese are so enthralled with fuzzy logic that last year *fuzzy* won two gold awards for most popular word.

"In Japan these days, everything is *fuzzy*, even toilet paper," Lotfi Zadeh, the father of fuzzy logic, told *IEEE Spectrum*, pronouncing the word the way the Japanese do—*fudgey.* "In the United States, it is a bad word, but in Japan it is a good word," said Zadeh, a professor of computer science at the University of California at Berkeley.

Fuzzy logic is being implemented in the control systems of a wide range of Japanese products, from camcorders and cameras to washing machines, microwave ovens, and vacuum cleaners. Modeled on the human intellect's ability to reason with approximate statements, not just all-or-nothing propositions, the technique allows system parameters to be ill defined or *fuzzy* in the description of system dynamics.

Zadeh admits to having had qualms about coining the term *fuzzy* in his seminal paper "Fuzzy Sets," published in 1965 in the journal *Information and Control*. "It is not a term typically found in scientific literature," he said. "When people do use it, it is usually in the pejorative sense."

Nonetheless, Zadeh went with *fuzzy* because it best described his theory. He felt that words like *soft*, *indistinct*, and *ill-defined* were too broad, since he wanted the word to give "the impression of something that is not sharp." *Blurred* was a close contender, but he decided it sounded worse than *fuzzy.*

As he foresaw, *fuzzy* did not sit well with some people. Rudolf Kalman (F), a mathematics professor at the University of Florida in Gainesville, wrote in 1972: "Let me say quite categorically that there is no such thing as a fuzzy scientific concept, in my opinion. We do talk about fuzzy things but they are not scientific concepts. . . .Some people in the past have discovered certain interesting things, formulated their findings in a non-fuzzy way, and therefore we have progressed in science."

Despite this comment and others that indicated "downright hostility" toward his concept, Zadeh said, if he had it all to do over again, he would still use *fuzzy.* "It's a double-edged sword," he said. "Some people don't like it, but it pricks up others' ears. On balance, I think the second effect is more important than the first."

In Japan, *fuzzy* can do no wrong. According to Matsushita Electric Industrial Co. senior engineer Harry Terai in Tokyo, the translation of the word changed recently, to a similar word meaning "clever" or "intelligent."

Beyond the fringe

People become more sensitive to word choice in discussions of a controversial technology—or the controversial effect of a technology.

Tony Leonardi (illustrations)

Perhaps the stormiest technological debate right now in the United States and many other countries concerns the health effects of 60- and 50-hertz electric and magnetic fields from power lines, substations, appliances, and so on. These fields are frequently referred to in the media as *non-ionizing radiation*—which sounds technical enough, but is not quite technically sound.

While in general it is appropriate to call electromagnetic waves *radiation* and to describe them as *non-ionizing* since no charged particles are generated except at very high frequencies, fields around power lines and appliances do not have the propagating nature of radiation.

Virtually none of the energy in power lines and appliances goes into propagating fields because they were not designed to radiate, unlike antennas. Radio-frequency and microwave fields—about 300 kilohertz to 30 gigahertz—emanating from antennas are of the propagating variety and may be properly termed *radiation*.

"Power lines don't meet the conditions needed to get radiation," pointed out J. Robert Ashley (F), a member of the IEEE Committee on Man and Radiation (Comar) who has conducted radar antenna research and has taught electromagnetism at the University of Colorado in Boulder. Aside from the fact that power lines carry current in three phases, Ashley said, an antenna properly radiating 60-Hz waves would have to be 1000 kilometers high because the wavelengths are so long. The fields around power lines are more correctly thought of as fringing fields, he said.

The initial focus of the debate over health effects of electric and magnetic fields was on the microwave and RF frequencies. When the focus shifted to the extremely low frequencies of power lines in the last few years, Ashley said, the terminology moved over, too.

Ashley and other Comar engineers object to the use of *radiation* in connection with power-frequency fields, not just because it is incorrect, but because it might conjure up associations with nuclear radiation in the public's mind, making it seem more dangerous than it is. Further, use of the term defeats attempts to educate the public about how the fields fall off relatively close to the source, said University of Washington (Seattle) electrical engineering professor Arthur W. "Bill" Guy (F).

The U.S. government's use of the term is inconsistent. A background paper called "Biological Effects of Power Frequency Electric and Magnetic Fields," issued in 1989 by Congress' Office of Technology Assessment, distinguished between what it called confined fields found near power lines and the propagating fields of RF and microwave antennas.

But that distinction is absent from another Government document, an Environmental Protection Agency review draft on the potential carcinogenicity of electromagnetic fields released in January. The agency lumped fields in both the extremely low-frequency range, defined as 3–3000 Hz, and the RF range, defined as 0.003–30 000 megahertz, together under the umbrella of *non-ionizing electromagnetic radiation*, which it calls NIEMR.

Ashley said that to be absolutely precise, the fields near power lines cannot be called electromagnetic fields—a term deriving from the electromagnetic waves radiating from antennas. In true electromagnetic fields, the changing electric field produces the magnetic field and vice versa, whereas in the fringing fields near power lines and appliances, the two fields are independent of one another. Consequently they should be referred to as electric and magnetic fields.

COORDINATOR: Karen Fitzgerald
CONSULTANTS: Anne Eisenberg, Polytechnic University; Pamela McCorduck, writer

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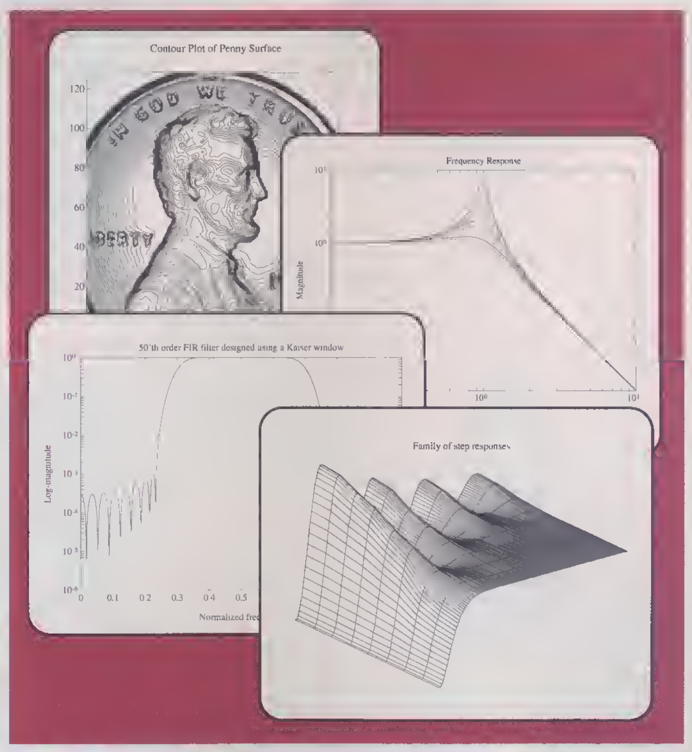

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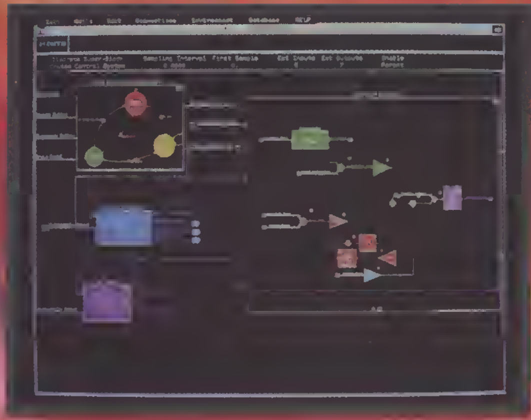

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Spectral lines

March 1991 Volume 28 Number 3

Aircraft traffic control

Last month our cover story on air traffic control in the United States emphasized two factors that contributed to the fatal landing of a USAir Boeing 737-300 on top of a SkyWest Metroliner III poised for takeoff on the same runway in Los Angeles.

One is the increase in annual departures from U.S. airports (up to 7.3 million from 5.2 million in 1983) with a concomitant decrease in the number of qualified air traffic controllers (down by more than 2000 from the 1980 level of 13 000). The other is the deficient control of planes on the airport surface.

Recent testimony before Congress indicated that controllers at busy locations work six-day weeks and 2 hours of overtime per shift with bare-bones crews. After the Los Angeles crash in January, the president of the National Air Traffic Controllers Association, Washington, D.C., said close calls involving two aircraft that have been cleared to take off and land on the same runway are not uncommon. He himself admitted to having given such clearances hundreds of times, but said he always caught the error through double or triple checking. During the Los Angeles accident, an assistant controller, called for by the Federal Aviation Administration, was apparently not on duty.

In *IEEE Spectrum*'s report, we noted that airport surface detection equipment (ASDE) designed in the 1950s is in routine use; it is noisy, its vacuum tube equipment is not very reliable, it is hard to repair, and it has difficulty detecting aircraft through rain or other precipitation.

Initial reports from investigators of the Los Angeles accident indicate that the ASDE was out of commission at the time, and suggest that it had been down for several weeks because a replacement part could not be obtained. An advanced digital ASDE system was to have begun service at U.S. airports in 1988, but the first one is just now under test at the Greater Pittsburgh International Airport, where it may be fully operational in from one to three years.

A third factor cited in *Spectrum*'s report may or may not have contributed to the Los Angeles accident. We reported that one problem nowhere close to being solved is the bottleneck of too many pilots communicating with a controller on one radio frequency—with pilots often unable to break through even in an emergency.

Marvin Smith, a professor at Embry-Riddle Aeronautical University in Daytona Beach, Fla., told *Spectrum* that about 70 percent of aircraft accidents involve some form of communications degradation, either radio problems or human misunderstanding.

The bottom line, one reviewer of the *Spectrum* report said, is that while there is no shortage of appropriate and applicable technology, there are severe problems in technology application and management in the U.S. air traffic control system.

Who's ahead in high tech?

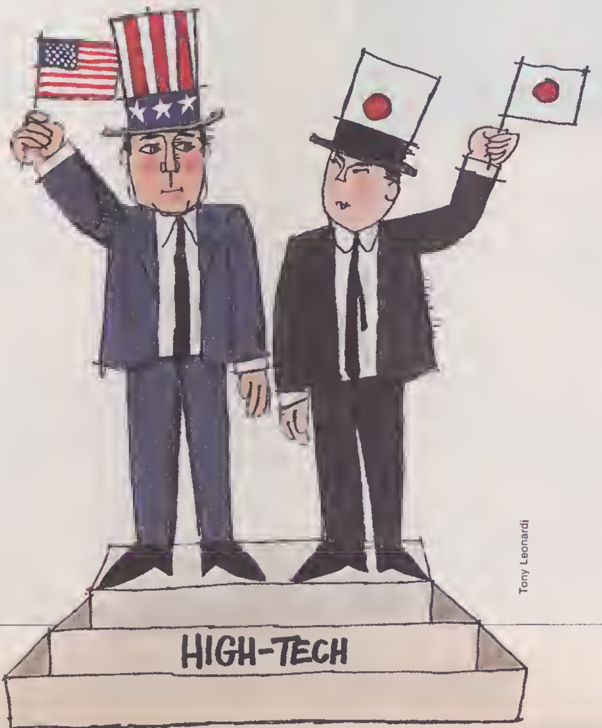
A recent survey of U.S. engineers showed that most believe the United States leads Japan in nine out of 12 high-technology areas. Where the United States was lagging, respondents said, was in consumer electronics, semiconductor memories, and "fifth generation" computers.

The poll, which queried a list of U.S. members of the IEEE, was conducted by the Gallup Organization Inc. and sponsored by Nihon Keizai Shimbun America Inc. for a leading Japanese business newspaper, the *Nikkei Industrial Daily.*

Some 65 percent of the respondents said the United States was technologically farther advanced in their own areas of research, while 19.3 percent thought Japan was ahead, and 10 percent called it even.

Space and aviation led those areas in which the United States was perceived as ahead, with 98 percent of the respondents so indicating, while new materials was at the lower end, with 60.7 percent.

On the other hand, Japan was seen to lead in consumer electronics (97.3 percent).



Tony Leonardi

Asked which categories the United States should push, 83.3 percent identified optical integrated circuitry. Nearly as many listed medicine to deal with cancer and Alzheimer's disease. The largest vote, however, was for "full and effective use of natural energy sources" (91.3 percent). Other categories to be expedited, each receiving about 75 percent of the vote, were nuclear fusion, intelligent robots, 1G-bit dynamic RAMs, high-speed surface transport, and artificial intelligence.

The most likely deterrents to technological advances were seen to be a reduction of capital spending for R&D by the United States (89.3 percent), a reduction of R&D budgets by private companies (88.7 percent), and a decline in the level of education (80 percent).

The results of the comprehensive poll will be reported in detail in a future issue of *Spectrum*.

Donald Christiansen

The DOE: agency under fire

A beleaguered Government office hopes to bring its unmatched resources to bear on vast ecological, economic, and safety problems

Fourteen years after its birth, the U.S. Department of Energy (DOE) is in the midst of a belated baptism by fire. With its nuclear weapons program showing the effects of long inattention and its civilian-energy programs in urgent need of coherence and direction, the DOE faces a challenge as monumental, arguably, as any confronted by a Government agency since World War II.

Now, as the department launches massive efforts to address these deficiencies, policies and decisions are being made that will set the course for the nation's defense-nuclear programs and energy use well into the next century. The implications are profound for a host of critical issues, including national security, the atmosphere and environment, competitiveness, and the fuels that will be used to drive the nation's economy—an issue vividly underscored by images of warfare in the Persian Gulf.

Glenn Zorpette Senior Associate Editor

The challenges are likely to tax the department's substantial resources: an annual appropriations budget of about US $13.5 billion (10th largest among cabinet-level agencies), a nationwide staff of 17 300, and about 130 000 contractor employees. The department also operates a network of nine premier scientific and technical laboratories, dozens of other special-purpose laboratories and facilities, and electric-power generation and marketing organizations in Alaska and the southeast, southwest, and Pacific northwest.

The problems in the weapons program, which have their origins in the creation of the country's defense-nuclear complex in the 1940s, are pervasive. News reports in recent years have described dangerous decay and unsafe managerial and operating practices at the nation's five nuclear materials production plants. High-level radioactive waste has leaked from corroding tanks at one of the sites, Hanford, Wash., severely contaminating groundwater.

The DOE also confirmed that its contractors had released low-level radioactive waste, dust and gas, and chemical toxins—sometimes routinely—at many of the sites. The magnitude of the problem is perhaps best illustrated by the DOE's admission that coping with it will take at least 30 years and require an environmental restoration effort that will eclipse its weapons program.

Overseeing the start of this massive cleanup is James D. Watkins, a retired U.S. Navy admiral whose expertise is in submarine propulsion. Appointed energy secretary in February 1989, he took over an institution that had in effect been condemned nine years before, when a dentist and former governor of South Carolina was appointed energy secretary with the express mission of dismantling his department. The undertaking proved impossible, but the attempt itself was debilitating, and the 1980s were characterized by shrinking budgets in nondefense programs and, by all accounts, a loss of direction and *esprit de corps*.

One of the most telling statistics concerning the past decade's effect on the DOE is that at the end of the Carter administration the department spent about two-thirds of its appropriations budget on nondefense work, including civilian energy programs, and the other third on defense. Today, the proportions are almost exactly reversed.

By the time of Watkins' arrival, the DOE had the reputation of being "a dumping ground for political appointees you don't want to put somewhere important," in the words of a long-time DOE observer in Congress.

"The Admiral is trying his damnedest to make something happen," said Daniel A. Dreyfus, vice president for strategic planning at the Gas Research Institute's Washington, D.C., office. "But he's coming off a bad situation: eight years of pretense that nothing should happen.

"When he started," Dreyfus added, "I would have said that the two most critical objectives were straightening out the weapons program and making progress on the nuclear waste issue. If he could bring some order to those, it would have been enough for four years."

But a few months after Watkins was sworn in as secretary of energy, President Bush directed him to give equal priority to another vast project: formulating a comprehensive energy policy—the so-called National Energy Strategy—to coordinate and direct virtually all major aspects of U.S. energy use, from regulation of natural-gas sales to conservation of energy through lighting design. The war in the Persian Gulf, with its implicit roots in petroleum trade issues, has lent considerable urgency to the strategy exercise.

A draft strategy, in the form of a list of about 60 policy options, was submitted to the President last Dec. 21. Key White House officials objected to some proposals and the list was returned to the DOE for revision. The draft was leaked to news organizations in October and again in February.

Whether the official document proves effective remains to be seen. Even if it does not, it will have accomplished something by forcing the department to address civilian energy issues comprehensively for the first time in almost a decade. ◆

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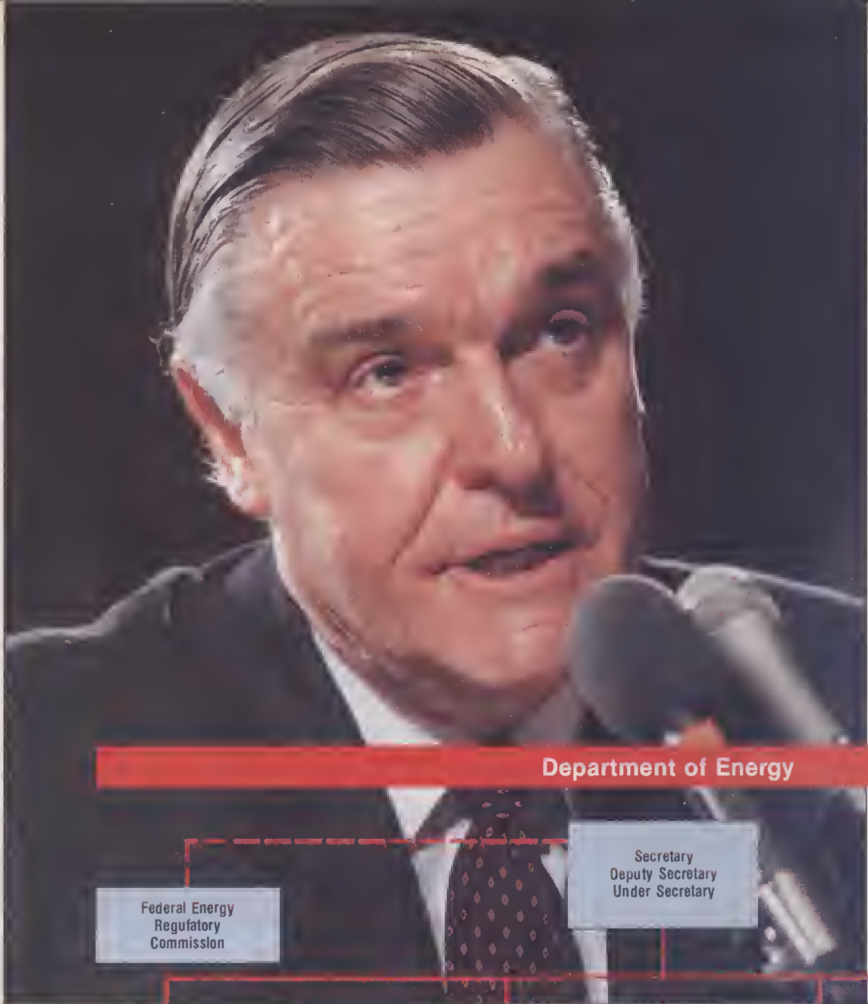
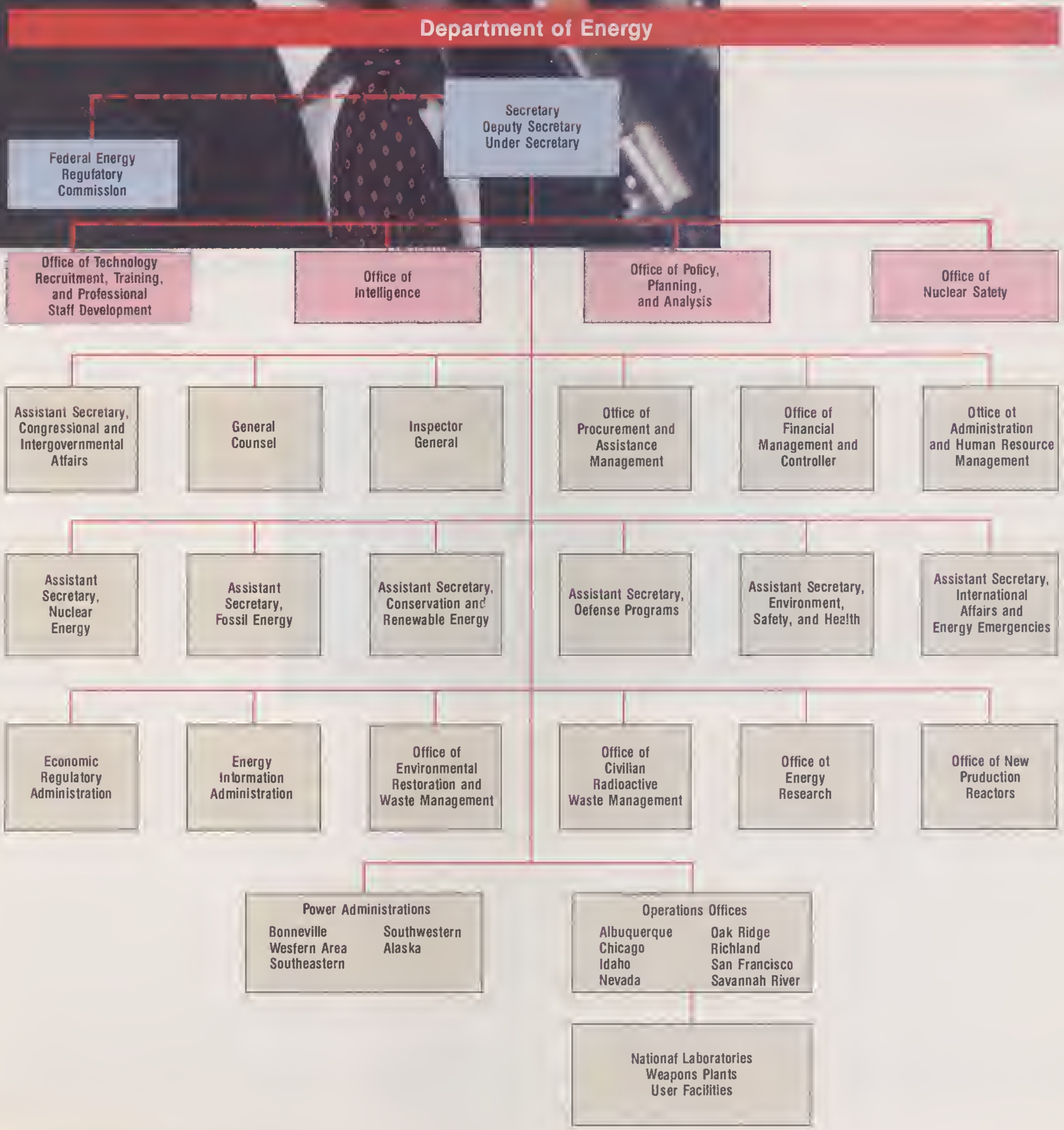


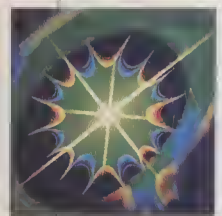
U.S. Department of Energy

Appointed in February 1989, Energy Secretary James D. Watkins (photo) inherited a department whose nondefense programs had been in decline for nearly a decade. Openly disappointed with the unevenness of the managerial staff he inherited, he has increasingly sought advice from top aides, such as his deputy and under secretaries (W. Henson Moore and John C. Tuck, respectively) and the director of the Office of Policy, Planning, and Analysis (Linda G. Stuntz). This has shifted the balance of power in the department, notes Peter D. Blair, a program manager in the Congressional Office of Technology Assessment. The power balance in the DOE is traditionally between the so-called line programs, which are headed by assistant secretaries, and other secretarial advisors, such as the offices now occupied by Moore, Tuck, and Stuntz.



Loosening the bonds of oil

A comprehensive 'National Energy Strategy' has at last been drafted, but has yet to overcome the hurdle of Congressional approval



By the time the massive U.S.-led attack on Iraq began on Jan. 17, the U.S. Department of Energy (DOE) was confident it could cope with whatever chaos befell the country's oil markets. Such chaos, however, never materialized. In fact, even while it prepared for the worst, the DOE had predicted the relative stability.

"It has gone so well, it's almost eerie," said Calvin A. Kent, administrator of the DOE's Energy Information Administration, Washington, D.C.

Months before the outbreak of hostilities, Kent's office developed five computer scenarios, or "games," depicting the likely impact on energy markets of five different versions of a Persian Gulf war. "It just so happens that what is actually happening is very close to one of those five situations," Kent told *IEEE Spectrum* in an interview the day after the initial U.S.-led attack on Iraq. These scenarios involved not only the DOE but also the departments of Defense, State, and Commerce, the National Security Council, and both Houses of Congress, as well as advisors from industry and media.

One outgrowth of the scenarios project was a Gulf Crisis Task Force, which was officially activated on the eve of the war after being set up and repeatedly drilled by U.S. Energy Secretary James D. Watkins and Under Secretary John Tuck several months before. Senior DOE managers, including Kent and assistant secretaries John Easton and J. Michael Davis, took turns leading the task force, which provides round-the-clock updates on fuel and energy matters related to the crisis. The team studied issues ranging from the amount of fuel needed to power the massive allied military effort, to the movements of fuel prices all over the world.

Even the threat of the Iraqi leader, Saddam Hussein, to use "oil as a weapon" was taken seriously by the team, which turned to Sandia National Laboratories in Albuquerque, N.M., for advice on coping with such an eventuality weeks before Saddam made good on his threat. Sandia's suggestion, to stop oil spillage into the Gulf by bombing oil-field manifolds and setting released oil on fire, was quickly implemented by allied forces, after consultations with engineers on site.

The team also did its best to calm the market as the war unfolded, reassuring Government and futures-exchange officials when offensive actions seemed to threaten critical energy supplies. Right after the outbreak of hostilities, for example, an Iraqi missile struck and ruptured a fuel tank at a small Japanese-Saudi refinery not far from the border of occupied Kuwait. Kent's staff immediately stated that the significance of the event from an oil-supply standpoint was minor, contradicting early television reports. "I spend a lot of time debunking rumors" of catastrophe, he explained.

STRATEGY WANTED. This and other DOE accounts portray the department as having done well in managing the impacts of war on U.S. energy markets. But as is also true with the Administration it serves, the Gulf war has diverted attention from more fundamental problems confronting the DOE that may plague the nation long after the war has ended.

> Congress wants more support for renewable energy, efficiency, and conservation

In the civilian-energy area, the most pressing of these problems, arguably, is the department's effort to develop a National Energy Strategy—one of the most significant initiatives in the department's brief history, and one made all the more urgent by the outbreak of war.

"Everyone's breathlessly awaiting" the energy strategy, said Daniel A. Dreyfus, vice president for strategic planning at the Gas Research Institute's Washington, D.C., office in an interview just before the war began. "A lot of resources were put into it, and with the Gulf situation, the National Energy Strategy is being colored by the view of some people that an energy problem is apt to get a lot of people killed."

As originally envisioned by the White House and the Energy Department, the strategy was to be a far-ranging one encompassing virtually every major aspect of U.S. energy use, including power generation by conventional, nuclear, and alternative means; independent power production, regulation, and transmission access; fuel production and regulation; energy conservation and efficiency; research and development; and transportation. DOE officials and critics alike also agreed that the strategy is urgently needed to head off a host of potentially serious energy-related problems, as indicated by:

- Pollution and global warming trends. Evidence is mounting of environmental damage caused by acid rain and "greenhouse gases."
- Growing dependence on fossil fuels and consequent vulnerability to supply disruptions—a trend dramatically underscored by the Gulf war. U.S. net daily consumption of imported oil will reach 10 million barrels a day by the end of the decade, according to the Energy Information Administration [see graph, p. 38].
- A lack of alternatives to fossil fuels. Through the 1980s, support for commercialization of alternative energy technologies withered, forcing many developers out of business. At the same time, the U.S. nuclear industry suffered a series of shocks and has not been able to expand beyond 20 percent of U.S. electricity production.

Besides addressing basic energy-supply and environmental problems, utility executives and officials in particular had also hoped the strategy would bring coherence to the DOE's diverse initiatives and research thrusts, likened to a "patchwork" by Kurt Yeager, senior vice president for technical operations at the Electric Power Research Institute (EPRI) in Palo Alto, Calif. Many also hope the strategy will strengthen U.S. competitiveness by bolstering the country's position in emerging clean-energy technologies that could become the basis of multibillion-dollar industries as countries expand their efforts to reduce pollution and greenhouse gases.

Glenn Zorpette Senior Associate Editor

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"We're in desperate need *now* of leadership from the Federal government on energy policy," said Jonathan Becker, energy policy analyst at Public Citizen, a Washington, D.C.-based public-interest advocacy group.

Unfortunately, however, some DOE observers contacted by *Spectrum* believe that the attempt to formulate the strategy has already become a quixotic quest, hobbled by squabbling between the Energy Department and White House officials over some specific proposals. These observers, including EPRI's Yeager, were skeptical that the strategy could emerge from these political battles with enough authority to do more than "encourage the status quo."

At press time, the DOE had not released details of the proposals comprising the draft strategy or of the recent discussions surrounding them at the White House. Like many confidential documents in Washington, however, the draft strategy was leaked to the press. In its Oct. 29 edition, *Inside Energy*, a McGraw-Hill trade newsletter, published some of the proposals; this report was expanded upon by a leak of the revised draft to several news organizations on Feb. 8. *Spectrum* obtained a copy of this latter draft; many of its proposals related to electricity production and consumption are summarized in the table at right.

PRODUCTION FIRST. The energy strategy project began in July 1989—four months after Watkins was sworn in as Secretary of Energy—when the Bush administration directed the DOE to formulate a comprehensive energy policy, the so-called National Energy Strategy. The White House also set the ground rules: the DOE would provide a list of energy-policy options to the White House, which would in effect create the strategy by choosing from the DOE's list.

This list, of about 60 policy options, was submitted to Bush on schedule last Dec. 21. Key White House officials, including Chief of Staff John Sununu, objected to some proposals related to energy conservation and renewable energy, and the list was returned to the department for revision. During the first week of February a revised draft was circulated among Federal agencies by the Office of Management and Budget; it was this draft that was disclosed to the press. This draft strongly emphasizes energy production—by fossil, nuclear, and other sources—over efficiency and conservation.

Precisely how the strategy proposals might be put into action—whether they might carry the full force of law, for example—could not be determined at press time. In speeches and DOE releases, Watkins has referred to the strategy as a "roadmap" and "action plan" on which the DOE and White House will base future DOE budgets and R&D initiatives. White House officials recognize, however, that an energy strategy perceived as weak on support for renewable energy, efficiency, and conservation would be rejected by Congress.

"It would be dead on arrival," confirmed Jack Riggs, staff director of the energy and power subcommittee of the House Energy and Commerce Committee. "You can't ask Congress to hurt the environment. You can't say there's an energy crisis when you want to promote oil and nuclear issues, and insist that the market take its course on energy efficiency and alternative fuels."

Congress, meanwhile, is not deferring to the executive branch on the issue; several bills have been introduced in both houses that would promote fairly comprehensive energy policies in their own right.

CABINET CLASHES. According to Congressional sources, some of the DOE's proposals, including several related to energy conservation, ran aground during meetings with key presidential advisors because the proposals were perceived as conflicting with the free-market principles espoused by the Reagan and Bush administrations.

The energy sectors whose development has been most hindered by this free-market stance are conservation and alternative and renewable energy technologies. Supporters of the latter technologies say their high initial costs generally preclude widespread adoption, without some form of Federal encouragement, typically in the form of tax credits or subsidies. They also note that the stated prices of fossil fuels do not account for more complex, indirect costs, such as those resulting from environmental damage, or from marshaling a massive military operation when supplies are jeopardized.

In essence, they say, the Administration's free-market vision is myopic. "Their

Highlights of the DOE's proposed National Energy Strategy

Energy conservation and efficiency
- Require that the Energy Secretary publish energy conservation standards for electric lights; require the Federal Trade Commission to prescribe rules for labeling lights
- Authorize loans from the U.S. Treasury for energy conservation measures at Government agencies
- Remove taxes from rebates awarded by utilities to customers who install high-efficiency lighting and appliances

Nuclear power
- Require the Nuclear Regulatory Commission (NRC) to consolidate construction- and operating-licensing into a single procedure incorporating inspection, testing, and analysis
- Require the NRC to resolve emergency planning before issuing the combined license; specifically, to disallow after issuance of the license any hearings based on "a decision of a state or local government to withdraw from participation in emergency planning"

Nuclear waste
- Allow the Energy Secretary to conduct, *without* a state or local permit, "site characterization studies" under the Nuclear Waste Policy Act of 1982, but also require the secretary to "consider the views of state and local officials" with regard to local laws affecting site characterization

Renewable energy
- Provide tax credits of up to 2 cents per kilowatthour (1.8 cents per megajoule) for those producing electricity with solar thermal, photovoltaics, wind, or "certain geothermal" and biomass technologies
- Remove power production limitations (80 megawatts) from eligible alternative-power plants

Reform of Public Utility Holding Company Act
- Allow both utilities and nonutility organizations to use a holding company structure to build and finance independent power projects not subject to the financial and corporate regulations of the holding company act

Transportation
- Require that a fraction of all automobile and truck fleets assembled after 1994 run on alternative (non-petroleum-based) fuels

Hydroelectric power regulatory reform
- Require the Federal Energy Regulatory Commission (FERC) to coordinate and consolidate licensing review for hydroelectric plants, taking into account the inputs of Federal and state agencies and Native American tribes
- Exempt projects that produce less than 5 MW from licensing requirements

Energy supplies
- Establish a program to lease lands in the Arctic National Wildlife Refuge's 600 000-hectare coastal plain for oil and gas exploration and drilling

Fuel regulation
- Replace existing FERC regulatory authority over oil pipelines with "streamlined common carrier obligations"
- Allow import and export of natural gas without prior Federal government approval
- Give the FERC sole jurisdiction over environmental impact statements for gas pipelines

pronouncements strike me as completely two-faced," said Becker of Public Citizen. "Despite all the free-market rhetoric, the Reagan and Bush administrations have been the greatest friends the nuclear and oil industries could hope for." As examples of intervention on behalf of those industries, Becker cited the depletion allowances and exploration tax-credits enjoyed by oil companies, and the fact that the Government does not require operators of nuclear plants to have insurance for the off-site effects of accidents.

In an interview, the DOE's Davis, who is assistant secretary for conservation and renewable energy, acknowledged that "the market we've got is not a free market. It has regulations, tax policies, and incentives.

"Do we understand the market well enough to predict the effect of incentives?" he continued. "Will they move the market in the direction of greater freedom, greater competition? If the answer is no, one ought to be real careful."

A DOE insider, who spoke on condition of anonymity, offered another view. "In order for [Watkins] to come out aggressively on energy efficiency, he'd have to take on Sununu, who thinks if energy use doesn't grow, the economy doesn't grow. And to do that [challenge Sununu], you have to do your homework." Sound research and development has been done in this area, the source said, but it is not yet reflected in top policy decisions, such as the National Energy Strategy proposals.

"The politics of energy efficiency and renewables are associated with Jimmy Carter," the source added. "And the internal politics are that if Jimmy Carter did it, it must have been stupid. It's a tremendous internal barrier we've been trying to overcome."

FUNDS SHIFT. During the Carter administration, development and commercialization of many of these technologies were supported through a combination of Government funding, tax credits, and a number of other incentives.

But the Reagan administration saw these incentives as interventions in the free market and eliminated many, particularly those related to conservation and renewable energy. The Carter administration's encouragement of certain technologies was derided as "throwing money at the problem."

The Republican strategy has been to emphasize basic research over development and commercialization, which were deemed the domain of industry, not Government. Between 1980 and 1990, DOE funding of basic energy research—including weapons-related research—rose 93.2 percent to US $2.4 billion; at the same time, however, funding of fossil, renewable, conservation, and nuclear R&D dropped 46 percent to $1.6 billion.

Though programs in renewable and alternative energy had been getting a relatively large share of development and commercialization funding, they declined precipitously during the 1980s—roughly 80 percent throughout the decade, according to the U.S. General Accounting Office. Partly because of this shift in funding, and partly because of a decline in oil prices, more than 150 U.S. developers and manufacturers of biomass, solar, and wind-energy technologies had closed up shop by the mid-1980s, according to Solar Energy Industries Association in Washington, D.C.

Notwithstanding this dismal recent history

The Office of Energy Research

If not for the fact that, organizationally, it is just another office in the Department of Energy (DOE), the Office of Energy Research would probably rank as one of the world's most renowned scientific and technical organizations.

With an annual budget of more than US $2.5 billion, the office sponsors more than 90 percent of all U.S. research in high-energy physics, over 80 percent of U.S. research in nuclear physics, and more than 5000 graduate students each year. It is overseeing construction of the world's largest colliding-particle machine, the world's brightest source of X-rays, and it recently embarked on a project to map the human genome—an endeavor that will take a decade or more and cost hundreds of millions of dollars.

"It's essentially a National Science Foundation built within the DOE," said Alvin Trivelpiece, a former director of the office who is now director of Oak Ridge National Laboratory in Oak Ridge, Tenn. And with the start of the Superconducting Super Collider (SSC) and human-genome projects, the office's stature and influence within the science and technology communities is likely to increase.

The office encompasses six main divisions devoted to high-energy and nuclear physics, the SSC, basic energy sciences, health and environmental research, fusion energy, and science education. With a hefty 120 percent increase proposed for its 1992 budget ($534 million was requested), the SSC is highest in profile. Construction began last year and is expected to continue until 1999.

As currently envisioned, the SSC will be a slightly oval ring 87 kilometers in circumference, buried more than 20 meters underground and completely surrounding Waxahachie, Texas, about 50 km south of Dallas. Inside the ring, proton streams will collide head-on with a total effective energy of 40 trillion electronvolts (TeV), 20 times the energy of the biggest other such collider in existence, the Tevatron at the Fermi National Accelerator Laboratory in Batavia, Ill.

Shortly after being declared the heart and soul of the Government's plans to keep the United States in the forefront of physics research, the project drew wide attention as its design was completed and its estimated price jumped from just over $5 billion to about $8 billion (it now stands at $8.249 billion). The DOE hopes to secure one-third of the total cost from sources other than the U.S. government, including the State of Texas, which has already pledged $1 billion.

Nonetheless, critics fear that such huge Federal expenditures, for not only the SSC but also the genome-mapping project and the National Aeronautics and Space Administration's space station, will shortchange hundreds of other, smaller Federal science activities. Officially, the DOE responds to such arguments by noting that Federal funding is allocated on a program-by-program basis, and cancellation of one large project does not free up money for other work.

The SSC will join three other major particle-accelerator machines already operated by the office's high-energy and nuclear physics group, and several lower-energy particle machines used primarily for investigations of electromagnetics, decay, and other properties of atomic nuclei. The Office of Energy Research is also responsible for coordinating and supporting virtually all Government research in magnetic confinement fusion, in which a high-temperature plasma is confined by an intense magnetic field.

Much of the DOE's long-term research in energy-related science and technology is handled in the office's Basic Energy Sciences group. Within


Brookhaven National Laboratory

Antibody labels, such as this gold one developed at the Department of Energy's Brookhaven National Laboratory in Upton, N.Y., enable biologists to see submolecular sites with much greater resolution.

this group are five subsections devoted to materials science, chemistry, engineering and geosciences, energy biosciences, and advanced energy projects. This group also supports fundamental research in mathematical, computational, and computer sciences, and manages a supercomputer access program based at Lawrence Livermore National Laboratory in Livermore, Calif.

The Health and Environmental Research division had its origins in post-World War II Government studies of the effects of energy-related phenomena—such as radiation and, more recently, global-climate change—on people, animals, and the environment. It has since expanded its mission to include biological, environmental, and similar research that uses the department's considerable facilities and resources. The largest-scale example of this latter activity is the human genome initiative, an ongoing, long-term effort to map and describe the entire human genome at the molecular level, an accomplishment that would greatly benefit biological researchers, including those trying to combat a host of genetic maladies.—*G.Z.*

1980–90 Department of Energy R&D budget, in millions of 1982 U.S. dollars

Source: Department of Energy, U.S. Congress (Office of Technology Assessment)

In the 1980s, the Department of Energy's research and development budgets declined in virtually all sectors except basic research (which included some defense-related work). The trends manifest the general antipathy of the Reagan and Bush administrations toward developmental and commercialization activities, which were deemed the province of industry. The sharply higher fossil R&D budget in 1990 reflected increases for clean-coal technology projects.

and the anticipated underrepresentation of efficiency in the National Energy Strategy, there are faint signs that renewable energy, conservation, and efficiency technologies may be headed for a modest resurgence. For example, a DOE spokesman pointed out that the 1992 budget request for R&D on conservation and renewable energy is more than double what was requested in 1989, during Bush's first year as President.

There are signs, too, that the free-market vision of some high DOE officials is not quite the same as that of other Administration notables. In his interview with *Spectrum*, Davis said he favored tax incentives or credits that were tied to the success of a program—in other words, rewarding projects that not only go into operation, but also operate well.

''My view is that we should shift from input to output incentives,'' he said. It is not clear that such proposals could pass muster at the White House, however.

CLEANER COAL. Of course, the DOE already supports development and commercialization of some energy technologies, mainly under a multibillion-dollar effort to advance systems to burn coal more cleanly. These include retrofit systems designed to remove pollutants from the smokestacks of existing plants, and more advanced (''repowering'') technologies, such as fluidized-bed combustion systems, which are inherently cleaner and more efficient.

The program is something of an anomaly, however. It was begun by Congress in the mid-1980s after the collapse of the Synthetic Fuels Corp., a far larger and more ambitious Carter administration program. The Reagan administration only embraced this ''clean-coal'' program later, in response to mounting pressure from the Canadian Government to stem the transborder flow of pollutants from midwestern U.S. power plants. In 1990 about $554 million was appropriated by Congress for DOE clean-coal projects, under a program in which the industrial partners that are developing the technologies contribute at least as much as the DOE.

In the wake of amendments to the Clean Air Act that will significantly reduce the amount of pollutant emissions from U.S. generating plants, utility officials are divided over the success of the DOE program, on which the department has spent some $1.3 billion since 1986. One prominent utility research expert, who requested anonymity, said that the program emphasized relatively low-cost retrofit solutions, such as dry scrubbers, which will be of little use in the face of the stringent new requirements.

''While we have spent a lot of money on clean-coal research, there hasn't been nearly the technological payback we might have gotten'' if more advanced options were emphasized, the source said. He acknowledged that the clean-coal program took this less ambitious course because it had its origins in politics and apparently did not accurately anticipate the extent of the recent Clean Air Act amendments.

The head of the DOE's clean-coal technology program, C. Lowell Miller, disagreed. ''We feel we've achieved a good balance between retrofit systems and more advanced repowering technologies that will help meet clean-air act requirements after the turn of the century.'' The balance between the two types was in effect set by industry itself, Miller added, noting that the DOE's selections were in line with the proportion of proposals received for each type. He also said the retrofit systems—some of which are now being demonstrated—are significant improvements over conventional ''scrubber technology.'' The systems will either control more forms of pollutants or operate more cost-effectively and with fewer waste by-products.

The department also plans to shift toward the more technologically advanced repowering technologies—including pressurized fluidized bed combustion and integrated coal-gasification combined cycle plants—in its fourth round of clean-coal projects, proposals for which are now being accepted.

Another sector that has managed to keep a few development projects going is nuclear energy; last year the DOE's Office of Nuclear Energy awarded Westinghouse Electric Corp., Pittsburgh, and General Electric Co., Fairfield, Conn., $50 million apiece to continue development of, and gain NRC certification for, advanced light-water nuclear reactors. The reactors are part of a group

now being developed with so-called "passive safety features" that their designers say will allow the reactors to cool themselves indefinitely in the event of an accident. Westinghouse, GE, and EPRI are sharing development costs with the DOE.

Overall, the DOE spent $341.8 million on nuclear fission energy R&D in 1990—a decrease of almost 80 percent, after inflation, since 1980. A similar amount, $320 million, was spent on magnetic-confinement fusion research, which is carried out principally at Princeton University in New Jersey and at two sites in California: General Atomics in San Diego, and Lawrence Livermore National Laboratory in Livermore.

Though sharply cut since 1980, the fission and fusion R&D programs still have relatively sizeable budgets, resulting in an uneven distribution of R&D funding. At present, funding is relatively high for coal and nuclear R&D and relatively low for all other R&D [see tables, p. 37].

"I don't think current programs represent a rational distribution of R&D funds," said the Gas Research Institute's Dreyfus.

Such an imbalance, as well as the shortcomings in the clean-coal program perceived by some, are precisely the sort of problems that the National Energy Strategy is intended to address and, ideally, prevent. Whether the strategy carries enough authority to achieve even this modest goal remains to be seen.

American Electric Power Co.

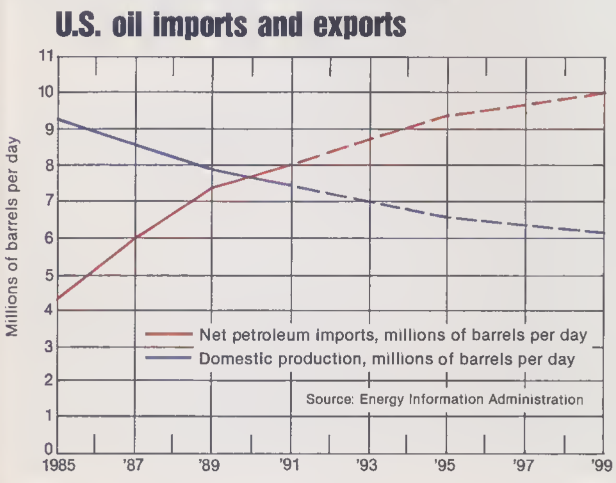
As coal burns inside the American Electric Power Co.'s Tidd plant, sulfur dioxide is absorbed by dolomite. This pressurized fluidized bed system, in Brilliant, Ohio, is the first of its kind in North America, and was built with support from the Department of Energy.

ORGANIZATIONAL PROBLEMS. The struggles between top DOE officials and other presidential advisors over the department's energy strategy proposals point up fundamental organizational problems, according to Dreyfus, who was staff director of the Senate Committee on Energy and Natural Resources when the DOE was formed in the late 1970s. He believes the department was crippled at the outset by its own organizational structure, which was modeled on the Department of Defense, a process- rather than resource-oriented organization. Thus the DOE has an assistant secretary for fossil energy, for example, but not specific people of high rank who focus exclusively and comprehensively on the petroleum industry or the coal industry or the electric-utility industry.

"Each of these industries is distinct," he noted. "They have their own movers and shakers, their own cultures, and their own financial approaches, because all of them are regulated to different extents. And each one is not easy for outsiders to understand." Under its current structure, the DOE requires industry representatives to deal with many officials on even relatively minor business, a situation that Dreyfus characterized as "chaotic."

He argued for a new structure, in which there are specific DOE officials "who feel that specific industry segments are their own ballparks—they know the key people, and know how that industry works.

"You need this inhouse expertise to make intelligent inputs for policy making. You also need it so that you have spokesmen who can take initiatives back to industries and speak with authority. . .and make things happen."



A possible side benefit of these closer ties to industry would be more identifiable constituencies for the energy secretary, which could support him in his cabinet dealings. "Take [Environmental Protection Agency Administrator William K.] Reilly," Dreyfus suggested. "He has a podium and a massive constituency of people who think he's an environmentalist. So if his inputs are rejected, the president's environmental scorecard goes down.

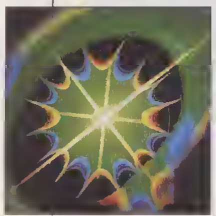
"Where's the admiral's constituency? Who's offended when he loses an argument? Who makes phone calls and goes to the hill on his behalf? Why aren't the electric rate payers his constituency?"

Such questions are likely to come to the fore as the United States emerges from a costly conflict that has its genesis in energy issues, and which many see partly as a consequence of drifting too long without a coherent energy strategy. But though war came on quickly, the national strategies that may help avoid it in the future will take many years to develop.

"The energy issues we face in the coming century are not something to be solved in crisis mode," said EPRI's Yeager. "These problems are going to take a sustained commitment over decades." ◆

Overhauling weapons production

The Cold War's ending and major safety problems are impelling the DOE to reduce and reconfigure its nuclear arms complex



In January, as the U.S. military gloried in the performance of its weapons technology in Iraq, the massive nuclear weapons production complex run by the Department of Energy entered its third year of paralysis, brought on by safety deficiencies and environmental problems at all of the 15 weapons sites across the nation. In early February, the department announced proposals for a far smaller complex that could no longer produce fissionable plutonium, but would make weapons from retired warheads and existing stockpiles of plutonium.

One incentive for downsizing the complex is the passing of the Cold War and reductions in the nuclear stockpile. Pending treaties could cut the current stockpile of 20 000 nuclear weapons in half, according to Stan Norris of the Natural Resources Defense Council in Washington, D.C. The Energy Department's reconfiguration plan considers stockpile reductions ranging from 70 to 15 percent of current warheads.

But a far greater stimulus for the new plan is, as Robert Alvarez, staff member of the Senate Committee on Governmental Affairs, put it to *IEEE Spectrum*, "the sobering realization of the true costs of nuclear weapons once you factor in cleanup, health, and safety costs." The committee has been the focus of Congressional efforts to resolve the problems of the weapons complex. These problems have in essence transformed the department from a weapons producer to an environmental agency with a cleanup budget of US $4 billion this year, far surpassing the $1.6 billion Superfund budget of the Environmental Protection Agency for cleanup of the nation's worst toxic waste sites. The total cost for cleaning up and improving safety over the next 30 years is put at $150 billion, plus another $50 billion for modernizing and updating the complex.

Acknowledging that the problems stem

Karen Fitzgerald Associate Editor

The U.S. nuclear weapons complex

Facility oversight	Operations contractor	Dates of operation
Albuquerque Operations Office		
Sandia National Laboratory Albuquerque, N.M.	AT&T Technologies (formerly Western Electric Co.) University of California	1949–93 1948–49
Los Alamos National Laboratory Los Alamos, N.M.	University of California	1943–92
Pantex Plant Amarillo, Texas	Mason & Hanger-Silas Mason Co. Procter & Gamble	1956–91 1951–56
Mound Facility Miamisburg, Ohio	EG&G Mound Applied Technologies Monsanto Research Corp.	1988–93 1947–88
Kansas City Plant Kansas City, Mo.	Allied-Signal Aerospace Co. Allied Corp. Bendix Corp.	1987–91 1983–87 1948–83
Pinellas Plant, Clearwater, Fla.	General Electric Co.	1957–92
Rocky Flats Plant * Golden, Colo.	EG&G Rocky Flats Inc. Rockwell International Corp. Dow Chemical Co.	1989–93 1975–89 1951–75
Idaho Operations Office		
Idaho Chemical Processing Plant Idaho Falls	Westinghouse Idaho Nuclear Co. Exxon Nuclear Idaho Co. Allied Chemical Co. Aero Jet Nuclear Idaho Nuclear Co. Phillips Petroleum Co. American Cyanamid Co.	1984–94 1980–83 1977–78 1972–76 1967–71 1954–66 1951–53
Idaho National Engineering Laboratory Idaho Falls	EG&G Idaho Aero Jet Nuclear Phillips Petroleum	1977–94 1972-76 1954-66
Nevada Operations Office		
Nevada Test Site Nye County, Nev.	EG&G Energy Measurements	1951–92
Oak Ridge Operations Office		
Extrusion Plant Ashtabula, Ohio	Westinghouse Materials Co. of Ohio Reactive Metals Inc. Bridgeport Brass Co.	1987–92 1963–87 1952–63
Feed Materials Production Center Fernald, Ohio	Westinghouse Materials Co. of Ohio National Lead of Ohio Inc.	1985–92 1951–85
Y-12 Plant Oak Ridge, Tenn.	Martin Marietta Energy Systems Inc. Union Carbide Corp. Tennessee Eastman Co.	1984–92 1947–84 1943–47
Richland Operations Office		
Hanford Production Operations (Fuel and Reactor Operations) Richland, Wash.	Westinghouse Hanford Co. Rockwell Hanford Corp. Atlantic Richfield Hanford Co. Isochem Inc. General Electric Co. E.I. du Pont de Nemours & Co.	1987–92 1975–87 1967–75 1964–67 1946–64 1945–46
San Francisco Operations Office		
Lawrence Livermore National Laboratory, Livermore, Calif.	University of California	1952–92
Savannah River Operations Office		
Savannah River Plant Aiken, S.C.	Westinghouse Savannah River Co. E.I. du Pont de Nemours & Co.	1989–93 1953–89

* Now reports directly to DOE headquarters.

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from four decades of putting production first over safety, health, and environment—in order to churn out a total of 60 000 warheads—the department has reversed the order of its priorities. Not only has it embarked on a huge cleanup effort, but under the leadership of Energy Secretary James Watkins, the department is instituting management changes designed to overturn what Watkins calls "a culture of secrecy and complacency." When he arrived at the DOE two years ago, *The New York Times* quoted Watkins, a former chief of naval operations who had worked in Admiral Hyman Rickover's nuclear navy, as being "aghast" at the condition of the complex.

Although indications of problems appeared sporadically through the 1970s and 1980s, the situation approached critical mass soon after the 1986 accident at the Chernobyl nuclear power plant in the Soviet Union. Some Government officials were disturbed by similarities in the designs of Chernobyl and the reactors at the Hanford Nuclear Reservation in Washington and the Savannah River Site in South Carolina; instead of containment buildings around the reactors, confinement systems filtered airborne emissions from the reactor buildings, and Hanford's N reactor, like Chernobyl's, was graphite moderated. Furthermore, the three 35-year-old Savannah River reactors and the 20-year-old N reactor were operating beyond their design lifetimes.

Within a month of the accident, then Energy Secretary John Herrington asked the National Academy of Sciences and the National Academy of Engineering (NAS and NAE) to assess the safety of the department's production reactors, as well as research reactors at the national laboratories.

PROBLEM EPIDEMIC. The first NAS study on the four defense production reactors, completed in early 1987, found an epidemic of problems in technology, operator performance, management, and safety policy. Acute aging was evident in stress corrosion cracking of reactor tanks and piping at Savannah River, and in expansion of the Hanford N reactor's graphite moderator, as well as in radiation-induced embrittlement of the reactor's metal components. Worst-case accident analyses were inadequate to provide a good picture of how the reactors might behave during an accidental loss of coolant, the NAS panel found, and the reactor confinement systems might not withstand the pressure brought on by a severe accident. Further, the panel criticized the discharge of radioactive liquids into open, unlined basins during normal operation of the N reactor and the potential for similar discharges during accidents at Savannah River.

After publication of the NAS report, the N reactor was shut down and put on stand-

Ashtabula

- Closed in tandem with Fernald
- Unsafe working conditions, including exposure to radiation (inspector below stands over uranium billet)


Robert Del Tredici


Robert Del Tredici

Fernald

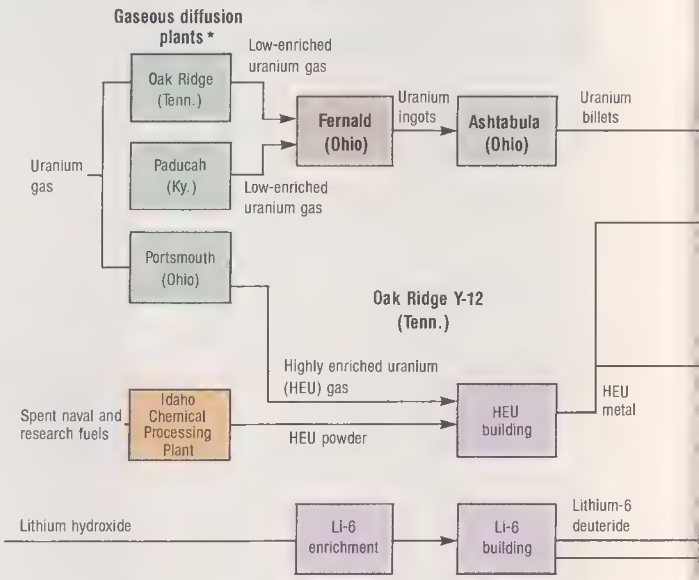
- Closed in 1988 when workers went on strike to protest unsafe working conditions, including exposure to radiation (worker above drills sample of uranium "derby")
- Hundreds of tons of uranium dust spewed into the atmosphere and into ground water and the Great Miami River
- Thousands of tons of uranium waste stored in leaky pits onsite

Idaho National Engineering Laboratory

(Idaho Chemical Processing Plant onsite)

- Toxic chemicals and 12.8-kilometer plume of tritium in aquifer
- Chromium, mercury, oil, and radionuclides contaminating soil

Nuclear weapons production



The nuclear weapons production process shown here is a simplified depiction of the production flow in the mid-1980s, before problems uncovered in the last few years permanently closed Fernald and Hanford. The process starts at the research, design, and testing facilities: Lawrence Livermore National Laboratory in California, Los Alamos National Laboratory and Sandia National Laboratory in New Mexico, and the Nevada test site 100 kilometers from Las Vegas, Nev. The upper portion of the flow is not critical right now because uranium and plutonium stockpiles are plentiful; but Energy Department officials want to restart the flow through Savannah River for production of tritium, a weapons material that must be replenished because of its 12.3-year half-life. Its three reactors are now shut down, but current plans call for a new reactor at Savannah River or another site. The Department of Energy has proposed moving the Rocky Flats functions to another site and reconfiguring the complex to reduce the current 13 sites (excluding Fernald and Ashtabula) to eight sites. Major problems (past and present) at some sites are listed above.

Oak Ridge Y-12

- Mercury (used to extract lithium from ore), arsenic, and other chemicals pollute East Fork Poplar Creek running through center of town of Oak Ridge
- Unsafe operating procedures, including mishandling of cyanide solutions


Department of Energy

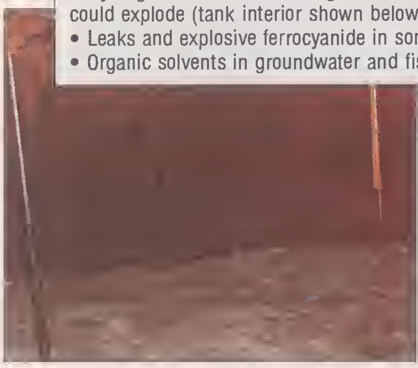
by. It has not operated since, and the department now plans to permanently stop production of nuclear materials at Hanford. Also as a result of the study, an oversight committee of experts, the Advisory Committee on Nuclear Facility Safety, was formed within the DOE to advise the secretary. Led by John Ahearne, a former chairman of the Nuclear Regulatory Commission, the committee has delivered some of the most stinging criticism of the complex in letters to the secretary. Congress also began legislation to create an independent oversight group, the Defense Nuclear Facilities Safety Board (DNFSB), which began work a year ago.

The 1986 Chernobyl accident did for the nuclear weapon's complex what the 1979 Three Mile Island accident had done for the commercial nuclear power industry. The safety lessons learned by the commercial industry in the early 1980s had not fed into a DOE isolated by its policy of secrecy and by the absence of regulation or oversight like that provided for commercial industry by the Nuclear Regulatory Commission (NRC). Though the DOE responded to the Three Mile Island accident by commissioning a study led by Jack Crawford on the weapons complex, its recommendations for safety improvements, which were along the lines of the NAS report, were largely ignored.

Troy Wade, the DOE's principal deputy of defense programs in the early 1980s, now president of AWC Inc., Las Vegas, Nev., told

Hanford

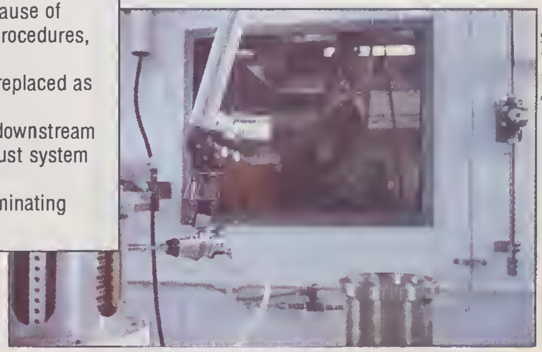
- N reactor closed in 1987 because of acute aging and release of radioactive effluents into open basin during normal operation
- Purex (plutonium-uranium extraction) closed in 1988
- Declared an environmental laboratory in 1990
- 20 X 10^{15} becquerels of iodine released mostly in 1940s and 1950s
- Hydrogen and nitrous oxide generation in one high-level double-shell waste tank could explode (tank interior shown below)
- Leaks and explosive ferrocyanide in some of 149 single-shell high-level waste tanks
- Organic solvents in groundwater and fission products in shrublands



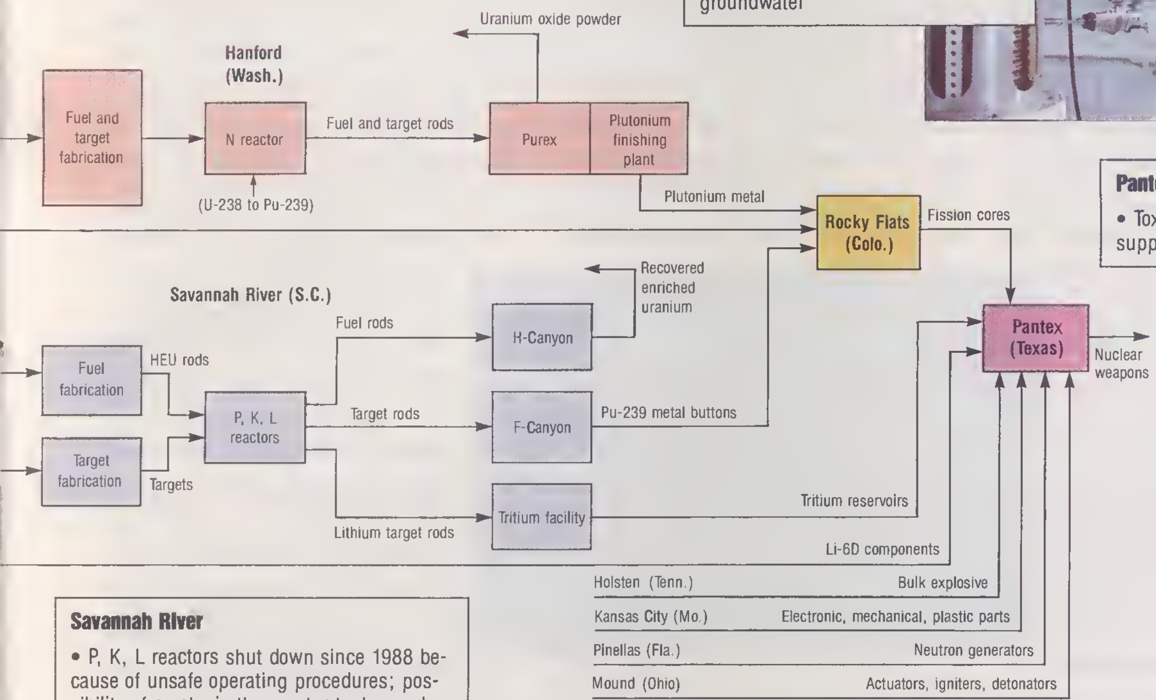
Department of Energy Office of Nuclear Safety

Rocky Flats

- Shut down in 1988 because of deficiencies in training, procedures, and maintenance
- Rockwell International replaced as contractor in 1989
- Fissionable plutonium downstream of filters in ducts of exhaust system
- Plutonium-239 in soil
- Organic solvents contaminating groundwater



Department of Energy



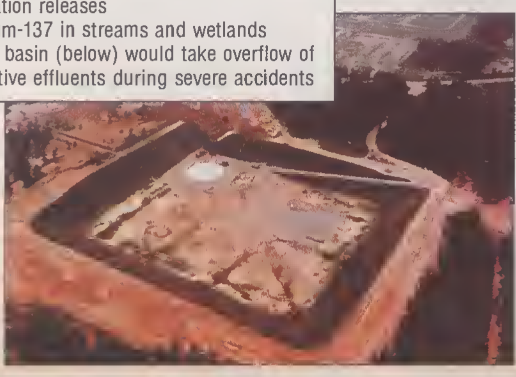
* These supply commercial reactor materials (now their only activity) as well and get their budget from the DOE's Office of Nuclear Energy. The Oak Ridge plant is permanently closed.

Pantex

- Toxic waste leaking into aquifer supplying Amarillo drinking water

Savannah River

- P, K, L reactors shut down since 1988 because of unsafe operating procedures; possibility of cracks in the reactor tanks; and confinement and reactor power limit design deficiencies
- Radiation releases
- Cesium-137 in streams and wetlands
- Open basin (below) would take overflow of radioactive effluents during severe accidents



Department of Energy-Savannah River

Kansas City, Pinellas, Mound

- Toxic chemicals contaminating soil, air, and groundwater
- Plutonium leaching into groundwater at Mound

Spectrum, "We didn't pay enough attention to the Crawford report. I think we got lulled into complacency by the fact that the safety records were good, the production goals were being met. We took some comfort in knowing that those reactors were quite different from any others in the country." The weapons reactors operate at much lower temperatures and pressures than commercial reactors.

In addition, the renewed emphasis on weapons production in the Reagan administration meant, according to Wade, that the production facilities went from operating at 25 percent of capacity during the Carter administration to "110 percent." Little money was left in the budget for maintenance and upgrades. Ironically, even in the Carter administration, Wade said, "when we told them we were going to have to spend a fair amount of money either to upgrade reactors or build new ones, they clearly weren't interested because they were antinuclear and antiweapons. When we went to Congress, they'd say, 'Your record last year was pretty good, you haven't hurt anybody there, you made your production goals—let's put it off for another year.'"

By the mid-1980s the increased stress on the complex's production capability had thrown the safety deficiencies into stark relief for the agency's officials. Consequently, Secretary Herrington began recruiting expertise from the nuclear power industry and the NRC. In late 1987 Richard Starostecki, then NRC director of inspections and technical assessments for all commercial reactors in the country, became the DOE deputy assistant secretary for environment, safety, and health—the agency's chief safety officer. Although he knew of the NAS findings, Starostecki told *Spectrum*, "It was quite frankly eye-opening and shocking to come to the Department of Energy."

IN THE PUBLIC EYE. In August 1988, with the heightened scrutiny of the DOE complex, an incident at a nuclear reactor at Savannah River triggered a breakthrough into the public consciousness. It highlighted the most insidious safety failures of the DOE's supervision: poor communication, unclear lines of responsibility, insufficient technical expertise, poor operator training, and deficient operating procedures.

A crew at Savannah River, operated by E.I. du Pont de Nemours & Co., was restarting the P reactor, one of three in working order there, after it had been shut down for four months so that the emergency cooling system could be reinforced against earthquakes. This was one of the first requirements derived from commercial practice in Herrington's drive for state of the art. The modifications were originally scheduled to take only a few weeks, but after the shutdown, seismic experts discovered more bracing was needed. The K and L reactors were also being modified, and it was imperative to get at least one reactor going again to meet production quotas. The three heavy-water reactors were the nation's only source of tritium, a radioactive isotope that increases the explosive power of nuclear weapons and must be replenished because of its short half-life (12.3 years).

While the P reactor was being started up on Aug. 7, the crew of operators and the reactor engineer noticed that the power was not rising as rapidly as expected. Though puzzled, they compensated by removing 61 more control rods than calculations had called for to reach criticality. After reaching 75 percent of allowed power, the reactor power level began dropping and on Aug. 9 it had to be shut down.

Du Pont engineers found that they had made the calculations with an incorrect xenon table and had ignored the four-month buildup of helium-3, a reactor poison generated by the decay of tritium in the core. These errors meant the configuration of rods prescribed by the engineers for power-up produced a core reactivity too low for a successful start. At this point Du Pont notified DOE of the problems by informing the Savannah River Operations Office, the DOE field group that monitors contractor operations on site. Both parties agreed the reactor could be restarted that day.

The following day, as the reactor was still powering up, a 2 percent increase in power showed up on all four of its high-level flux monitors. Within a minute, an operator brought the surge under control by inserting control rods. The reactor crew had never seen a power spike registered on all four monitors (except when there was rod motion), but continued the start-up, waiting 24 hours to notify the DOE of the spike. On Aug. 11, for the first time the operations office apprised the onsite representatives from the headquarter's Office of Environment, Safety, and Health (called the EH office) of this and the previous problem and they in turn notified DOE headquarters.

> DOE lacked technical inquisitiveness, which means being smart enough to ask the right questions

EH was charged with overseeing operations at all sites in the complex, but not until Starostecki took charge did EH place representatives on-site. Previously the checking had been done almost exclusively on paper. "I realized there was a real need for hands-on inspection shortly after I arrived at the department," he said. "In January 1988, when I was being introduced to the various Savannah River plant managers and the vice president, the people with me from the local field office were being introduced to them at the same time."

If EH representatives had not been on-site, DOE headquarters might never have learned of the P reactor incident. The Washington, D.C., office at once sent a technical review team, which on Aug. 15 recommended shutting the reactor down, not because of any unsafe condition of the reactor, but because all members of the crew acknowledged in interviews that they neither understood nor cared to learn the cause of the anomalies in the start-up. (The engineering department had not explained to them the discrepancies in the calculations.) This particularly alarmed the EH team since in the previous 20 years of operation no more than 30 control rods over the calculated number had ever been removed. Further, the crew indicated that since it had adhered to operating procedures, it would do the same again in a similar situation.

Indeed, the standard operating procedures contained no guidance for anomalous events. Since the operators had not been trained in basic reactor physics or in handling nonroutine events, Starostecki noted, lack of written guidance was a serious liability. In the commercial arena, the development of a technical rationale and the upgrading of procedures for such anomalies had been routine since 1983, as a result of an accident at a nuclear power plant in Salem, N.J.

The DOE's assistant secretary for defense programs at the time was Troy Wade. "I was shocked at what happened during the restart," he told *Spectrum*, but added that it did not reflect operations at all sites. "Worker radiation exposures at most sites have gone down every year. That says there were some safety programs that were working. Nobody ever talks about those."

EXPERTISE SHORTFALL. The shallowness of its technical expertise forced the Savannah River Operations Office to rely on Du Pont for technical assessment during the P reactor incident. Over the years, this reliance had turned the office from departmental supervisor into a contractor service organization, Starostecki said. And since all the weapons sites were Government-owned, contractor-operated (GOCO) facilities, the same was true of most other field offices. Often an office would defend "its contractor" to DOE headquarters.

"What any contractor or consultant wants more than anything is a good customer, who knows what he wants and lays out his expectations," Starostecki said. "Over the past two decades the relationship between the field office and contractor had eroded to the point where the office worked with the

Department of Energy Office of Nuclear Safety

Beginning in 1968, double-shell steel tanks (under construction at left) were built underground at the Hanford Nuclear Reservation to store high-level radioactive wastes. In the late 1970s, chemists discovered that explosive hydrogen and other gases generated in one tank were causing the waste slurry to swell by a few inches and then collapse every two to three months. The tank's vapor space, normally maintained at a negative pressure to contain gases, was being pressurized during the waste's growth periods—possibly enough to push radioactivity out through unfiltered maintenance ports or cracks (below) in the concrete cap over the tank.

contractor to promote production and viewed the contractor as the customer. DOE has to learn to be a good customer."

Secretary Watkins has several strategies for raising the agency's technical proficiency and environmental and health expertise. In 1990 he created an Office of Technology, Recruitment, Training, and Professional Staff Development, headed by Starostecki, to set agency-wide standards for hiring and training new personnel. The measure of the success of this group, Starostecki said, will be the level of technical inquisitiveness at contractors and the field offices. "Technical inquisitiveness requires a fundamental change in attitude," he said. "It means if you see something out of the ordinary, you are smart enough to ask the right questions and then you fix it before it breaks."

Watkins has successfully lobbied for legislation that lets the agency hire retired military and Federal employees—from the Navy's nuclear submarine program or the NRC, for example—without the usual requirement that their pension be reduced by the amount of their new salary. He is also working with the Administration to designate a number of jobs at the department as critical positions. This category can carry salaries much higher than civil service positions, but is limited to 500 scientific and engineering positions throughout Government.

SAFETY CONCERNS. The P reactor incident also highlighted weaknesses in the reporting relationships and management structure in the agency. The EH group, both the onsite contingent and the review team from headquarters, had been forced into an adversarial position against the field office and Du Pont. When EH recommended a shutdown on Aug. 15, DOE field officials invoked a DOE order requiring EH staff to prove a clear and present danger before ordering a shutdown. Consequently, the reactor was not powered down until Aug. 17, when Du Pont management and the field office manager agreed it should be. "Too often EH is perceived as more of a problem than a solution," said Starostecki.

Watkins recognized that EH's problems reflected a fundamental flaw in the structure of the DOE. The headquarters Office of Defense Programs paid the operating budget for the sites, and had the job of ensuring that the complex met production goals. But that office had no responsibility for environment, safety, or health; nor did EH have any budget authority to implement its safety goals or to clean up waste—only to issue safety policies. Thus production always came first, and EH was seen as an impediment to it.

Watkins has augmented Defense Programs' responsibilities. It must now ensure safety, protect the environment, and set up self-assessment groups that would identify and correct problems before others find them. EH acts as a second level of oversight to ensure adherence to its safety policy. To give nuclear safety a higher profile, Watkins removed that responsibility from EH and created an Office of Nuclear Safety on a par with EH. EH now oversees worker safety—compliance with Occupational Safety and Health Administration (OSHA) standards, which includes radiological and fire safety—and environmental compliance with the National Environmental Policy Act (NEPA) and Environmental Protection Agency (EPA) guidelines in the storage and management of wastes.

In the past, the department encouraged high output by awarding fees to contractors based on performance evaluations made by field managers. Over the decades, these fees became almost automatic, and since the field managers themselves got bonuses on the order of $13 000 if their contractor performed well, it was in their interest to pump up the contractor's performance. Officially, performance in environment, safety, and health accounted for 10 percent or less of the evaluation, while production performance accounted for 40–50 percent. Watkins has modified the award system so that 51 percent of the evaluation comes from the environment, safety, and health aspects of the company's performance.

In 1984, National Lead of Ohio (NLO) Inc., manager of the Feed Materials Production Center in Fernald, Ohio, received $1.3 million in bonuses in addition to its usual fee of $1.3 million for operating the plant. Just five months before the award, a critical study of the plant, commissioned by the Oak Ridge operations office, reported it to be so poorly managed that workers were routinely exposed to hazardous radiation levels. Moreover, thousands of pounds of uranium dust were being released into the air and groundwater during normal operation.

Yet Oak Ridge field manager Joe La Grone rated NLO's performance excellent, and NLO received three-quarters of the allowable bonus. The following year, after a large uranium leak at Fernald was made public, La Grone declined to award NLO a bonus, and a short time later the company decided not to manage the plant any more.

GATHERING STORM. The uranium releases at Fernald were revealed to the public in Congressional hearings shortly after a worker strike for higher wages and safer working conditions shut the plant down in October 1988. The hearings, as well as a series of reports in *The New York Times*, publicized the P reactor incident and other problems at Savannah River, Rocky Flats near Denver, Hanford, and the Waste Isolation Pilot Project in Carlsbad, N.M., a new repository for low-level wastes. That month marked the turning point for the department's nuclear weapons program. Fernald, which Troy Wade acknowledged was a "management disaster," never reopened and is now permanently closed while the department's new Office of Environmental Restoration

and Waste Management restores the environment there, where thousands of tons of uranium waste were stored in leaky pits. The new office's assistant secretary Leo Duffy estimates it will take 30 years to restore the site to green pasture.

Hanford, too, has been relieved of its production function and has been turned into an environmental laboratory. Richard Claytor, the DOE assistant secretary for defense programs, told *Spectrum* that the country has plenty of low-enriched uranium metal and weapons-grade plutonium, and that consequently, Fernald and Hanford are no longer necessary in the production chain. But Claytor stressed that the department will continue to make weapons from existing stockpiles and retired weapons. "With our current requirements," he said, "we definitely need to produce nuclear weapons for the foreseeable future, for many years."

None of the Savannah River reactors was restarted after October 1988, despite the Reagan and Bush administrations' assertions that immediate restart was critical to maintaining the supply of tritium. The DOE's 1992 budget indicates that the P reactor will be shut down permanently. Rather than two new reactors as originally proposed, the department's plan now calls for only one, which will be devoted to tritium production.

The most far-reaching option in the reconfiguration plan announced in February would reduce the 13 current sites to only eight by consolidation and streamlining of functions. The Rocky Flats plant, which has been closed since fall 1988, would be relocated to one of five existing sites in the complex or a new one. Its functions would be consolidated with those of either the Oak Ridge Y-12 plant or the Pantex plant or both.

Aside from streamlining the production process, the department feels it necessary to move Rocky Flats, Claytor said, because of the enormous local opposition to the plant and its proximity (24 kilometers) to Denver. The site's watershed feeds drinking water supplies for two Denver suburbs. Nonetheless, he said the department plans to restart operations at the plant this summer to meet weapons requirements.

The plan also proposes letting private industry supply the non-nuclear parts now made at the Pinellas, Kansas City, and Mound plants and eliminating those sites.

MOPPING UP. Many environmentalists complain that since the new plan is independent of the environmental restoration and waste management program, the new complex may produce environmental problems as serious as the current ones. Duffy counters that the sites now must comply with environmental laws. Until recently, the DOE had frequently argued that it was exempt from EPA and state environmental laws. "From the early to mid-'80s the Department of Energy was constantly seeking generic exemption from compliance with a variety of environmental laws," said Senate staff member Alvarez. "We read reports where they said, 'If we have to comply with these laws, we're going to effectively curtail weapons production.'"

But in the last few years, suits brought by such organizations as the Natural Resources Defense Council to force compliance have been succeeding. Watkins set up tiger teams last year to inspect each site for violations of not only environmental laws but also worker safety laws like OSHA's. The teams have so far completed 18 visits. But a weakness of the teams, noted by Ahearne's committee, is that though they categorize problems, they do not sufficiently flag major problems for upper management.

For example, the Hanford tiger team itemized 1271 violations of OSHA standards and 266 safety and health concerns at the site. Yet when the team briefed Ahearne's committee on its findings, there was no mention of what the committee views as the most serious problem—the possibility of explosions in tanks of high-level radioactive waste buried underground at Hanford. Particularly frightening is the generation of hydrogen and nitrous oxide gases in double-shell tanks. This condition was revealed to the public only in March 1990 shortly after the current Hanford contractor, Westinghouse Electric Corp. in Pittsburgh, briefed Congress' oversight board, the Defense Nuclear Facilities Safety Board, on the problem.

> High-level radioactive wastes at Hanford were swelling, burping gases, and collapsing

Yet Rockwell International Corp. in El Segundo, Calif., Hanford's previous contractor, knew of the problem as far back as 1977 when it discovered that one tank's wastes—topped by a hardened, crusty layer—were growing at a rate of about 1 percent per month, burping gases, and then collapsing. By 1980 several chemists had noted the generation of nitrogen, nitrous oxide, and hydrogen and the potential for explosion. But in over 12 years the company did nothing except monitor it periodically with poor instrumentation and take one core sample—not for analyzing gas generation but for corrosion analysis of the waste. Also, because Rockwell was required to keep the waste in the tanks below a certain level, the company occasionally lanced the waste with pressurized water or air. A July 1990 study of the problem by the newly created Office of Nuclear Safety noted that the core sampling and the lancing activity might produce sparks. Should ignition occur, the report said, flammable constituents in the crust could cause a secondary burn or explosion, possibly more violent than the first reaction.

Perhaps indicative of the clash of the past and future cultures at the DOE, the Nuclear Safety office—headed by Steve Blush, former staff director of the NAS studies—heavily criticized Rockwell, Westinghouse, and the DOE Richland Operations Office for poor management of the tank farms, for keeping the problem under wraps, and for doing nothing substantial to correct it. It also rebuked Westinghouse for portraying the problem as a new concern last March.

But Troy Wade countered, "It is patently incorrect to say that the hydrogen problem at Hanford was covered up and that nothing was done about it. There were lots of measurements made and things attempted. It was never believed by competent authority to present a major problem. People put off buying new tires for their cars when they don't have the money because they are willing to accept the risk. That same sort of cost-benefit argument is made every day in the DOE."

The cost of cleanup at Hanford and other sites now is so high that some question whether it can realistically ever be accomplished. "Right now there are 100 acres [40 hectares] of contaminated land for which no technologies exist to return them to their original condition," said Alvarez. "If we are unable to return portions of these sites for habitability, will we be engaging in a policy of creating national sacrifice zones?"

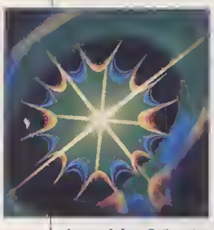
Alvarez also questioned whether the DOE has the expertise in-house to deal with the problems. Many of the techniques the DOE proposed for monitoring gases in the Hanford tanks, he said, show an ignorance of state-of-the-art practices in private industry. DOE environmental restoration assistant secretary Duffy acknowledged that the department needs to double its current staff of environmental engineers, but complained about "the severe lack of environmental talent in the United States."

But there is optimism about change at the DOE. "If you go back a year, the tiger teams were finding that there had not been a full buy-in at the DOE field offices and contractors of the secretary's initiatives," said Paul Ziemer, assistant secretary of the Office of Environment, Safety, and Health. "We're starting to see now that there is."

Starostecki is heartened, too. "It took the commercial sector on the order of 10 years to develop fully accredited training programs and revised qualification standards for reactor operators," he said. "We're only three years into the process. My judgment is there's an awful lot of things that are still broken, but we're on the right path." ◆

Origin of a culture

The DOE inherited the secrecy engendered by the concern for national security at the Atomic Energy Commission



As a direct descendant of the Atomic Energy Commission (AEC), the Department of Energy (DOE) retained many of the institutional genes of the organization hatched in 1946 from the atomic bomb's Manhattan Project. The department's present-day problems can be traced to the secrecy, isolation, and lack of outside assessment built into an agency that had been given, as the first AEC chairman David Lilienthal put it, "a terrible responsibility."

On the heels of World War II and the first use of atomic weapons at Hiroshima and Nagasaki, a nation dismayed by the bomb's destructive power was ready to concentrate on peaceful uses of the atom—from electrical power and desalting sea water to food preservation. Though the Army had managed the Manhattan Project, many in Congress felt that only a civilian agency could oversee nuclear weapons production and at the same time shift the focus to peaceful applications.

There were others who believed that only the military could guard atomic secrets against Communist espionage. The United States had decided soon after the war not to share with any other country—not even Britain, Canada, or France—the engineering and manufacturing technology needed to make nuclear weapons. President Truman believed that "if they catch up with us on that, they will have to do it on their own hook, just as we did." In the end, advocates of a civilian agency won out, although the 1946 Atomic Energy Act created a Military Liaison Committee to work with the new agency.

Harsh questioning at Congress' Joint Committee on Atomic Energy confirmation hearings for the five commissioners centered on secrecy concerns, revealing what Lilienthal called hysteria over Communist aggression in eastern Europe. Nonetheless, Lilienthal and four other nominees, all strong supporters of a civilian agency, were eventually approved. As the Cold War set in, secrecy concerns intensified through the 1950s.

Karen Fitzgerald Associate Editor

The Atomic Energy Act required that personnel be subjected to security investigations unprecedented in the U.S. government. Although Lilienthal attempted to uphold civil liberties, the hysteria of the times sometimes crept in. In 1954 the commission went so far as to revoke the security clearance of J. Robert Oppenheimer, the scientific director of the Manhattan Project's wartime weapons program, then working as a consultant for the commission. The commission's decision was primarily based on his associations with left-wing radicals, which were known when he was hired for the Manhattan Project ten years before.

Soon after the inception of the commission, a number of security breaches and stolen documents put greater pressure on the AEC to render its fortress impenetrable. In one case Congressman J. Parnell Thomas gained access to Oak Ridge and employee files there in order to demonstrate that a civilian agency could not provide the necessary security. Charging in *Liberty* magazine that the production plants were "heavily infested" with "Communist suspects," he advocated returning the Manhattan District to the Army—as did six bills then pending in Congress for repeal of the Atomic Energy Act. A subsequent investigation by the joint committee found no glaring lapses in security, but recommended more guards and better security facilities.

Preoccupied with security issues, the joint committee paid little attention to overseeing the technical aspects of weapons production. Charges of "incredible mismanagement" at the commission made in 1949 by the committee chairman, Senator Bourke Hickenlooper of Iowa were directed primarily at lax security standards—as manifested in a case of missing uranium from Argonne National Laboratory in Illinois—and cost overruns at the Hanford site. The outcome of hearings on the charges was a report by the committee majority vindicating the commission and pointing to the growing stockpile of atomic weapons and the weapons tests at Eniwetok Atoll in 1948 as evidence of the agency's success.

The joint committee, created by the Atomic Energy Act, was the agency's only oversight and rarely questioned health, safety, and environmental policies. The agency was not bound by any laws in these areas either. As current Deputy Secretary of Energy W. Henson Moore noted in a speech at the Rocky Flats plant in Colorado on June 17, 1989, "The [AEC] philosophy was: This is a secret installation, not subject to any laws of the United States or the state of Colorado. [Its] job was to produce the secret and necessary ingredients for our nation's defense and nobody was to interfere."

UNPRECEDENTED POWERS. No Government agency ever before in peacetime had been given such sweeping powers as the AEC. James Newman, a principal author of the Atomic Energy Act, noted in his 1948 book, *The Control of Atomic Energy*, that the commission was granted the same constitutional powers as those required to conduct war. Quasi-legislative, quasi-judicial, and executive powers were necessary to create a Government monopoly on atomic energy sources and prohibit private activity. Newman wrote, "The powers were conferred by Congress only with profound misgiving and after prolonged soul-searching. . . . In passing [the act], Congress implicitly recognized that under the disintegrating force of the atomic bomb, the ancient institutional forms, honored and familiar though they were, had become obsolescent. For it is apparent that in the atomic age, in times of international unbalance, there is no limit to what the state will have to do in the name of security."

The authority was given to the AEC out of the conviction that nuclear weapons would ensure the nation's freedom. Furthermore, if the secrets of the weapons could be kept within the country, many believed world peace could be maintained.

External scrutiny was also limited simply because most politicians did not understand the sophisticated technology involved in the agency's mission. The mention of national security or secrecy needs easily deflected most outside questioning of its practices, including its atmospheric testing program.

When the Manhattan District facilities were transferred to the AEC, there were 2000 military personnel, 4000 civilian Government employees, and 38 000 contractor employees. Contractors like General Electric Co. had built and operated the first nuclear weapons factories. Under the Atomic Energy Act, the commission could have operated the facilities with Government employees, but the production of nuclear weapons was so complex that the commissioners felt only the best engineering corporations had the expertise to carry it out with the speed required.

The AEC was able to provide effective

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contractor oversight, at least on nonenvironmental technical issues, as long as it retained the technical expertise of the Manhattan Project personnel. But the late 1970s brought an exodus of technical talent as a result of the abolition of the AEC and the apportionment of its commercial regulatory responsibilities to the Nuclear Regulatory Commission, and its weapons production and energy research functions to the Energy, Research, and Development Administration. (Two years later this entity became the DOE.) Much of the expertise went to the NRC and industry. With no capability to challenge the technical and safety decisions of the contractors, DOE officials in effect threw off the reins of control.

Another early AEC decision contributed to this effect. As a precaution against enemy attack, espionage, and operating accidents, the Manhattan District sites were isolated and dispersed across the country. The AEC retained this idea, and Lilienthal added another dimension by his philosophy of decentralization. He believed it not only a good management technique (since operations could not be efficiently managed from a remote headquarters), but also an essential element of a democratic society. Consequently, he gave the agency's field offices the authority to make important decisions, a policy that carried through to the 1980s. When the field offices lost technical expertise, the sites were islands unto themselves, operated freely by contractors.

PRESSURE TO PRODUCE. Weapons development and production was the top priority for the agency. It was obeying a mandate from the country's leaders to manufacture a large number of nuclear weapons as rapidly as possible. Production received even greater emphasis after the first detonation of an atomic bomb by the Soviets in 1949; energy research was pushed further into the background. Disheartened by his inability to focus the agency on his dream of developing civilian energy applications, chairman Lilienthal resigned in 1950.

By the mid-1950s, there was "an inexorable shift in the Commission's aims from the idealistic, hopeful anticipation of the peaceful atom to the grim realization that for reasons of national security, atomic energy would have to continue to bear the image of war," wrote AEC historians Richard Hewlett and Francis Duncan in their 1962 book *Atomic Shield*. The Korean War reinforced the shift. By 1964, the country had produced so much plutonium that President Lyndon Johnson shut down eight reactors at Hanford, Wash., (leaving only the N reactor, then in construction) and one at Savannah River, S.C.

All this was happening at a time when environmental concerns were not a priority for the nation. Caroll Wilson, the first general manager of the AEC, wrote in the June 1979 *Bulletin of the Atomic Scientists*: "Chemists and chemical engineers were not interested

To consolidate the energy-related offices throughout the Government and to reshape them to fit national energy strategy, the Department of Energy was formed in 1977 from the agencies to the right (only major constituents shown). The Energy, Research, and Development Administration, with responsibility for nuclear weapons production and energy research, accounted for the bulk of the new organization. Regulation of the commercial nuclear power industry went to the Nuclear Regulatory Commission in 1975.

Lawrence Livermore National Laboratory

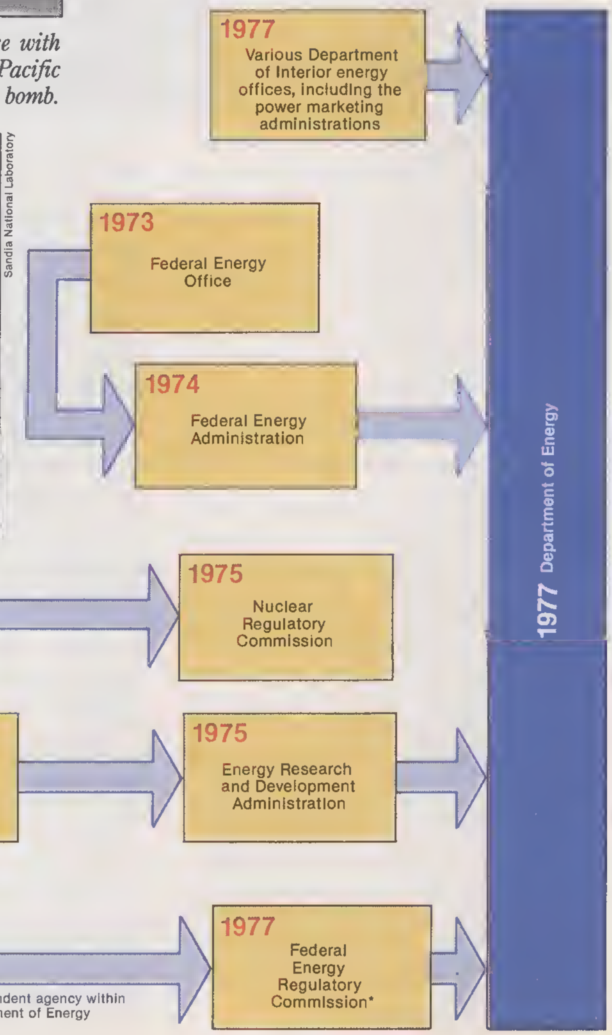
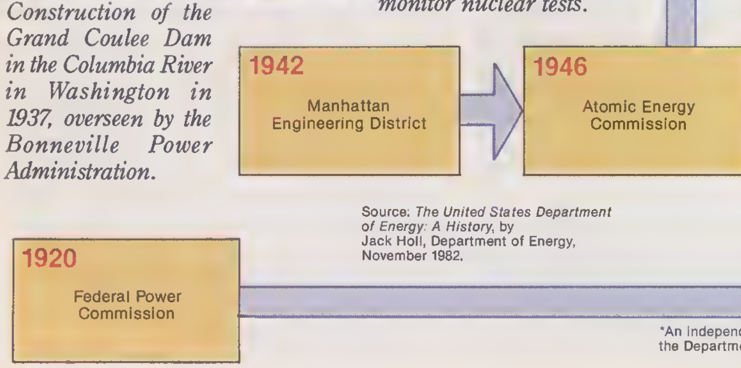
Nobel Prize winner Ernest Lawrence with Edward Teller aboard ship in the Pacific Ocean for 1951 tests of Teller's hydrogen bomb.

Sandia National Laboratory

President John F. Kennedy during a 1962 visit to Sandia National Laboratory, beside a satellite used to monitor nuclear tests.

Bonneville Power Administration

Construction of the Grand Coulee Dam in the Columbia River in Washington in 1937, overseen by the Bonneville Power Administration.

Source: *The United States Department of Energy: A History*, by Jack Holl, Department of Energy, November 1982.

in dealing with waste. It was not glamorous . . . it was messy; nobody got brownie points for caring about nuclear waste. The Atomic Energy Commission neglected the problem. . . .The central point is that there was no real interest or profit in dealing with the back end of the fuel cycle."

The management of high-level radioactive wastes that came from plutonium production at the Hanford and Savannah River plants is a case in point. From 1944 to 1964, the agency and its predecessor built 149 carbon steel underground tanks ranging in capacity from 55 000 to 1 million gallons (200–3800 cubic meters) at Hanford. The AEC saw this practice as an interim measure, with the ultimate goal of vitrifying the wastes for final geological disposal.

According to a July 1990 report on the Hanford tanks by the DOE's Office of Nuclear Safety, it had become apparent by the early 1950s that there would soon be a shortage of tanks. Consequently, the wastes were concentrated by adding potassium ferrocyanide to precipitate highly radioactive cesium-137 from the solution, and the liquid was pumped out to make room for more wastes.

More than 100 metric tons of cyanide were added to the tanks during these so-called scavenging operations. Beginning in the early 1970s it was discovered that 66 of the Hanford tanks had developed leaks. The AEC responded by building double-shell tanks at both Hanford and Savannah River. Liquid wastes from the leaking single-shell tanks were concentrated through an evaporation and crystallization process and moved to double-shell tanks through the early 1980s.

But in 1982 Harold Van Tuyl, manager of the Pacific Northwest Laboratory's analytical chemistry laboratory at Hanford, pointed out that the mixture of ferrocyanide, nitrates, and nitrites in the single-shell tanks could explode at high temperatures. According to the nuclear safety office report, he was concerned that proposals for removing liquid from the tanks and backfilling with rock to stop leaks would raise temperatures to dangerous levels.

A subsequent 1984 report presented a worst-case analysis showing the potential for an explosion equivalent to 36 tons of TNT. Known as the Burger report, the study was not approved for publication by the DOE because of the need for further studies, but funding for those studies was denied. Furthermore, the DOE continued to pursue the backfill idea for three more years.

Only a year ago, the DOE revealed an even more serious problem with the double-shell tanks. Since the late 1970s, one of the Hanford tanks has been inexplicably generating hydrogen and nitrous oxide, a mixture with greater potential for explosion than the ferrocyanide in the single-shell tanks, according to the nuclear safety office report. Many authorities cite this as the most serious problem in the nuclear weapons complex today.

HEALTH AND SAFETY. By the 1930s, the illnesses of medical professionals and radium-dial painters had revealed the dangers of external gamma radiation and internal alpha emitters. The knowledge of the effects of low-level doses of radiation has been refined in the decades since. But recently revealed radiation releases and worker radiation exposures at Hanford and Fernald, Ohio, indicate that the hazards of radiation were often not taken seriously enough.

Many instances can be attributed to negligence, but some releases were planned. In one experiment at Hanford in 1949, 5500 curies—200 terabecquerels—of radiation were released (about 20 curies—750 gigabecquerels—were released during the Three Mile Island accident) to test equipment for detecting radiation.

Troy Wade, president of AWC Inc., who worked for the AEC and its successor agencies from 1958 through 1989, told *IEEE Spectrum* that the releases were necessary to learn "what we needed to do to protect our facilities and to learn more about what our adversaries were doing." Secrecy was vital, he said, and stressed that AEC authorities did not believe that the information then available indicated a danger to public health and safety.

No interest was shown in the back end of the fuel cycle

But declassified documents show that Hanford health specialists recognized the risk, and that plant managers felt it was worth taking for the nation's security. High incidences of cancer and thyroid disease have been reported in the area, and studies are now under way to determine whether these are linked to the radiation releases.

The AEC succeeded in manufacturing 60 000 nuclear weapons and developing nuclear power. But the secrecy that was seen as all-important to that goal failed to keep nuclear weapons out of other countries' hands and exacted an enormous price in damage to public health, to the environment, and, perhaps worst of all, to public trust of government science.

TO PROBE FURTHER. The most in-depth study of one of the Department of Energy's most important predecessor agencies is the two-part *History of the United States Atomic Energy Commission*, tracing energy and defense activities from 1939 to 1952. Both parts are newly available in paperback editions from the University of California Press in Berkeley. A third volume, *Atoms for Peace and War*, takes the history through 1961, and is available in hardcover from the University of California Press. All three are by Richard G. Hewlett and various co-authors. A fourth work, now in progress, is expected to carry the story to the AEC's disbanding in 1975; it is being written by Roger M. Anders and Terrence Fehner.

Last year saw publication of several studies of the DOE's energy research activities. From the Congressional General Accounting Office came at least three: *Energy R&D: Conservation Planning and Management Should be Strengthened*; *Energy R&D: DOE's Allocation of Funds for Basic and Applied Research and Development*; *Energy Policy: Developing Strategies for Energy Policies in the 1990s*. Copies are available free of charge from the General Accounting Office, Box 6015, Gaithersburg, Md. 20877, or by calling 202-275-6241. A somewhat more technical and focused report, *Confronting Climate Change: Strategies for Energy Research and Development*, is available from the National Academy Press, 2101 Constitution Ave., N.W., Washington, D.C. 20418; 202-334-3313.

The DOE's own Oak Ridge National Laboratories looked to the future in "Energy Technology R&D: What Could Make a Difference?" For a copy, contact the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, Va. 22161.

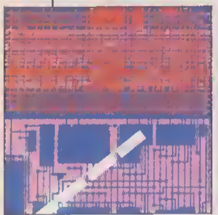
The study that spurred the Government to resolve problems in the nuclear weapons complex is the National Academy of Sciences' report, *Safety Issues at the Defense Production Reactors*, published by the National Academy Press in 1987. Two follow-on studies by the academy are *Safety Issues at the DOE Test and Research Reactors* (1988) and *The Nuclear Weapons Complex; Management for Health, Safety, and the Environment* (1989).

DOE plans for the weapons complex are described in *Nuclear Weapons Complex Reconfiguration Study*, published by the department in January 1991 and available from the National Technical Information Service [see address above]. A comprehensive study of the environmental challenges the DOE faces, *Complex Cleanup: The Environmental Legacy of Nuclear Weapons Production*, was just released in February by the Office of Technology Assessment. It is available for $10 under serial number 052-003-01222-7 from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402-9325.

A five-year study of problems in waste tanks at Savannah River is reported in *Deadly Crop in the Tank Farm*, published in 1986 by the Environmental Policy Institute, 218 D St., S.E., Washington, D.C. 20003. ◆

Cutting the high cost of testing

A new modeling approach to the overly long testing of analog and mixed-signal devices saves substantially on time and cost



The responsibility for production-testing a new line of low-cost 13-bit analog-to-digital converters is yours. You must devise a test plan that can correctly sort the devices into performance bins. What do you do? You test the first few to come off the assembly line extensively, examining how accurately the digital outputs correspond to the analog inputs and storing the results, which often deviate from ideal behavior.

Even though you are using the latest automatic test equipment, you notice that testing a 13-bit analog-to-digital converter (ADC) at all its possible output codes requires measuring 8192 (2^{13}) different values of input voltage—a very time-consuming task. And that is just for the room-temperature tests at nominal supply voltage. More thorough testing could take several times longer.

To keep production flowing, you realize that you may have to buy more test stations. But that capital investment would force up the price of the converters, supposedly low-cost devices. You long for a simpler test plan, one that would let you sort those converters accurately into the performance bins without increasing your costs.

Test engineers are constantly faced with that challenge: how to develop test routines that will correctly sort devices at minimum cost. There are inevitable tradeoffs between the expensiveness and thoroughness of the testing; for a given cost, the more complete the testing, the lower the throughput.

Over the last several years, a comprehensive approach that optimizes the tradeoffs associated with production testing of analog and mixed-signal electronic devices has been developed at the National Institute of Standards and Technology (NIST), Gaithersburg, Md. It is based on the fact that the behavior of many devices is governed by a relatively small set of underlying variables, which consequently determine the results of a large number of measurements. In essence, a simple linear coefficient matrix model of the device is set up to relate the (relatively large number of) measured responses to the (relatively small set of) underlying variables.

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This approach, an extension of the well-studied technique known as optimal design of experiments, is then coupled with the concept of empirical modeling. Although much more computationally efficient than the optimal design technique, the new approach yields nearly as good results. Early evaluations of its use in small-scale commercial experiments indicate its probable utility in situations where the candidate test space is large or otherwise expensive to test exhaustively, and where a rather few underlying parameters affect many aspects of device behavior—as is true with analog ICs.

In addition to testing converters, the approach is being applied successfully to a variety of devices and instruments, including amplifier-attenuator networks, filters, and multirange instruments.

Despite such achievements, however, this approach may not be as effective in other instances. Unless a model is already available, the method is best suited to large production runs where the cost of developing the model and selecting test points can be amortized over a large number of devices. Also, certain types of nonlinear behavior can seriously reduce the efficiency of any linear modeling approach.

LESS IS BETTER. Let us assume that the initial tests done by the test engineer on the first eight devices in our a/d converter example yield the results shown in Fig. 1. For simplicity, a fictitious 7-bit converter is illustrated with 128 (2^7) code states.

Although it is probably not known to the test engineer, and not obvious from the performance plots, the nonideal behavior of the converters is largely determined by rather few semiconductor-processing variables, here assumed to be seven [Fig. 2].

To find a solution for a system with seven variables, seven independent equations, or pieces of information, are required. In Figure 2, the seven curves on the top represent the error signatures of the seven variables.

Each variable is associated with a parameter that affects the behavior of the device in a particular way. For example, parameter a_1 causes the entire response to be offset, whereas a_2 causes a positive offset in the lower half of the response and a negative offset in the upper half.

On the bottom of Fig. 2, the production run performance of device No. 8 is shown to be a linear combination of these seven signatures; the weight of each is the value of the corresponding variable. (The process is conceptually similar to the idea behind Fourier analysis, in that a function is decomposed into a set of differently weighted standard functions.)

In this system, each candidate input test condition, or test point, defines a linear equation; the total error at each point is a linear combination of the seven signatures evaluated at the same test point.

The standard way to test ADCs is to do all-codes testing—run the input over its range so that all possible output codes are generated. A 7-bit converter requires performing at least 128 tests, with 128 separate equations—one for each required value of input voltage. But, since only seven independent equations are needed to solve the system, only seven test points need to be measured to calculate the values of the seven variables. Once those variables are known, the entire behavior of the ADC can be calculated—rather than measured—at every required test point by weighting and summing the seven error signatures.

Therefore, the test engineer really needs to test the converters under only seven conditions to fully characterize them.

Defining terms

Error signature: the characteristic way in which an underlying variable contributes to the total error response of a device.

Integral nonlinearity (INL): a figure of merit for an analog-to-digital converter, equal to the maximum deviation from the ideal input-output curve, not counting the gain and offset errors.

Normalized prediction variance: the ratio of the variance of a prediction to the variance of the measurement noise on which it is based.

QR factorization: a standard method for factoring a matrix into a right (R) triangular matrix and an orthonormal (Q) matrix—usually done to make machine solutions less subject to computer roundoff errors.

Residual errors (residuals): the part of a device's response that is not described by the model.

Test point: an input signal or other condition applied to a device under test, to which an ideal response can be predicted; it is also called a test condition or input condition.

Test space: the total range of input variables over which a device is tested.

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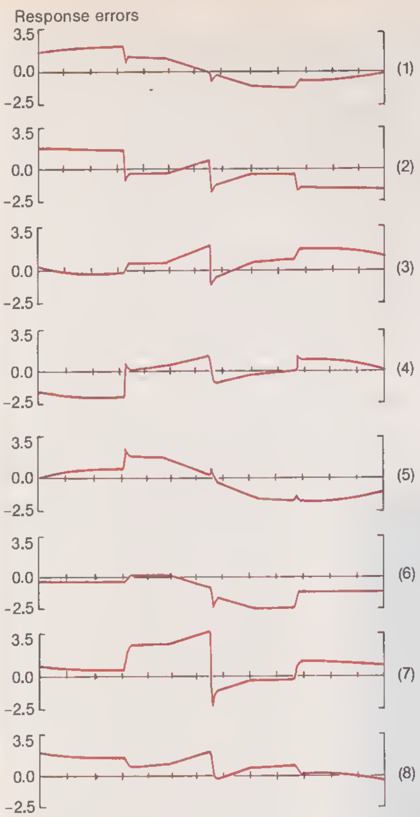
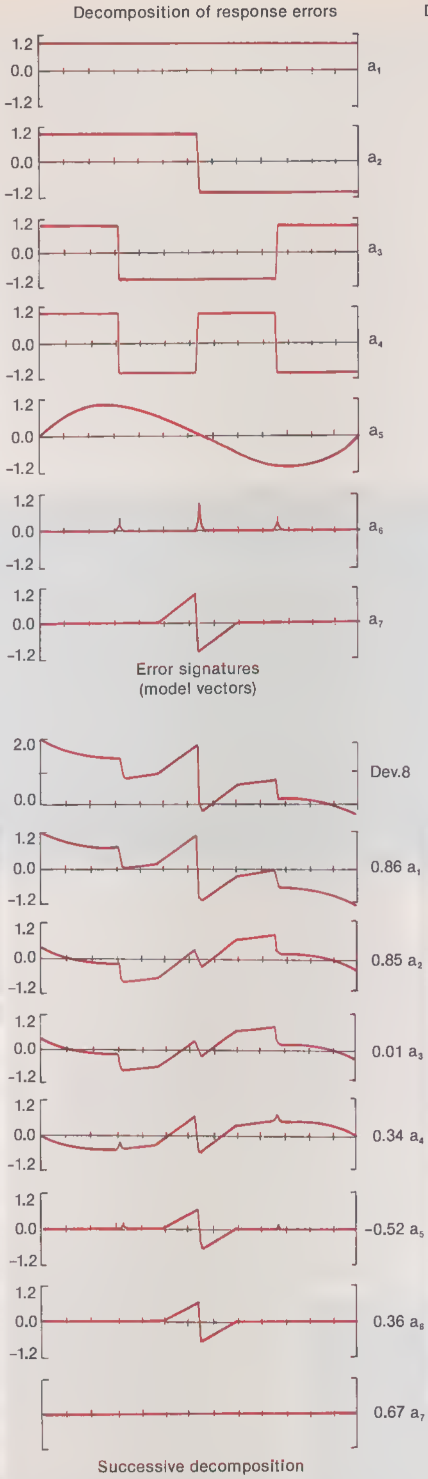
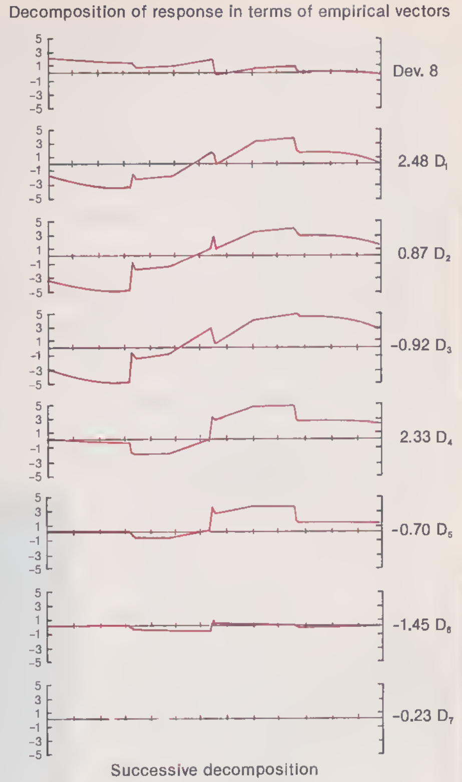


[1] The performance of a device as a function of one input condition can be illustrated by plotting the response error as a function of the input condition. In this case, the horizontal axis represents the digital output codes of a fictitious 7-bit analog-to-digital converter and the vertical axis is the input error corresponding to that code—the difference between the actual input that produced the digital code and the input that should ideally produce it. The scales are in arbitrary units.



[2] The error response of a device can be decomposed into a weighted sum of error signatures of underlying variables. The error signatures for the analog-to-digital converter example are shown at the top, and the decomposition of the response errors of Device No. 8 of Fig. 1, in terms of those error signatures, is shown on the bottom. The topmost plot on the bottom is the response of Device 8; the other plots show the error that remains after the designated amount of each error signature is successively subtracted.



[3] In addition to calculating error signatures from a known model, one can develop a model empirically—that is, from measurement data. In the case shown, based on the measured responses of Fig. 1, the empirical vector derived from seven of the devices provides a means for describing the behavior of the eighth.

To make this method work, two things are needed: the error signatures (or a matrix model from which they can be determined) and the specific set of test points at which the measurements are to be made.

WHERE TO TEST. Many different sets of seven test points will produce seven independent equatons, but many more will not. To complicate matters further, there are degrees of independence as well. What needs to be done is to find the set of test points that is maximally independent. Discovering that set also makes the process most resistant to the corrupting effects of measurement noise.

QUICK, BUT GOOD. Finding a set of maximally independent test points is handled by the optimal design of experiments process. For large problems, this can be expensive to find; however, nearly optimal solutions can be rather cheap using a mathematical operation called QR factorization (QRF). Computationally efficient implementations of the QRF operation exist in the public domain software called Linpack by the Society of Industrial and Applied Mathematics, Philadelphia, and in its friendlier commercial descendants, such as CLAM from Scientific Computing Associates Inc., New Haven, Conn., and Matlab from Mathworks Inc., North Natick, Mass.

Those routines operate on the matrix model of a device from simple calls to the software package. They return a vector (list) of the selected test points and also provide information on the degree of independence represented by them. From the vector of test points, the system of corresponding simultaneous equations is known. That small system of test points and equations is valid for every device that is adequately described by the original model.

A measure of the prediction errors associated with the selected test points is the normalized prediction variance. This can be computed ahead of time from the original matrix model and the selected test points and then evaluated at every candidate test point given a set of selected test points.

A good selection of test points, therefore, is one that minimizes the prediction variance. If that variance is deemed too high even with a maximally independent set of test points, the error can be further reduced by adding more test points so that more measurements exist than the number of parameters to be estimated.

Of course, adding those test points will re-

sult in an overdetermined system of equations (more equations than variables), but that can be solved using standard least squares techniques. If the additional test points again constitute a "good" selection, the prediction variance will be reduced by the ratio of the number of test points to the number of variables.

Beating down the noise is not the only advantage of selecting more than the minimum number of test points; the redundancy permits model errors to be detected as well. Selecting additional test points enables a least squares solution to be found, allowing the generation of the residual errors of the solution at the measured points. Examination of those residuals can give a good indication of the accuracy of the model: a good model will produce residuals that are randomly distributed and have a standard deviation comparable to that of the measurement noise.

On the other hand, an inadequate model will cause the standard deviation of the residuals to increase, and structure to appear in the distribution.

Once measurements have been made at the selected test points, the system of seven equations is solved, again using standard matrix software routines. The solution gives the actual values of the seven variables for the specific device that was tested.

Referring back to the fictitious ADC example, the entire behavior of the converter at all of the 128 candidate test points is then easy to predict: the seven error signatures are simply weighted by the corresponding values from the solution, and then summed together. The result is the behavior for all test conditions, including the few that were actually measured, and the many that were not. For a 13-bit converter, the savings could be even greater, as will be seen later.

MODELING. Of course, the success of the method depends critically on the quality of the model. So far, it has been assumed that the error signatures for the converters were known. How they are to be determined, and how accurate they must be, are the next questions to be addressed.

In mathematical form, the model really represents the sensitivity of the converter's behavior, at each test condition, to an appropriate set of underlying variables. The variables determine the degrees of freedom available to the devices—the specific ways in which individual units can deviate from their nominal, or ideal, behavior. In some cases, the variables are known from the design and correspond to conventional modeling parameters.

> Be aware that with device complexity, model accuracy degrades

For example, if an accurate equivalent circuit is known, the error model can be computed as the partial derivatives, or sensitivities, of the output response of the circuit with respect to the component parameters, evaluated at their nominal values. (That corresponds to a first-order Taylor expansion of the circuit's response.) Versions of public domain as well as commercial software are currently available for computing such sensitivity matrices. The well-known circuit analysis program Spice 3C, for example, has that capability.

Models derived in that manner are called physical, sensitivity-based models. Their primary virtue is the direct correspondence between the model variables and measurable physical parameters, such as resistance, capacitance, transistor transconductance, and open-loop gain.

The power of high-throughput test systems such as Teradyne Inc.'s A500 can be increased manyfold by the application of modeling techniques for designing test procedures.

Teradyne Inc.

But physical modeling is not without problems. As devices get more complex, model accuracy tends to degrade and the computational burden increases. All too often, adequate modeling and computer-aided design (CAD) tools seem to lag behind the technology that requires them. In some cases, detailed design knowledge of the device may simply not be available to the test engineer. In others, a first-order Taylor expansion may be insufficient. That can occur when the device's behavior has a strongly nonlinear dependence on its components, as in testing the frequency response of a multi-pole filter, for example.

EMPIRICISM. For such situations, other modeling techniques are available. Empirical learning-based modeling, in particular, is especially attractive for performance-testing applications like the ADC example. It requires no detailed design knowledge of the device, nor is it strictly limited to linear dependence upon the variables.

In empirical modeling, the models come from the devices themselves. For that reason, they are immune to the sorts of errors that can arise from an imperfect understanding of the workings of a device. After all, what could better express the process variability of a series of widgets coming off a production line than the behavior of the widgets themselves.

If empirical modeling is applied to the converter example and a sample of the devices is fully tested—and all test points examined —the responses of the various devices will vary somewhat. This is because the values of the underlying variables differ from unit to unit. (If that were not true, testing would be unnecessary.)

Assuming a stable manufacturing process, a reasonable statistical sampling of devices will embody all the degrees of freedom that the process allows. Using the same QRF routine employed in selecting test points, a subset is chosen of response vectors that are linearly independent. The new matrix composed of this subset will itself be a complete model useful for accurate predictions.

Mathematically speaking, the new matrix spans the space of possible responses, but these in turn are constrained by the variables of the manufacturing process. Figure 3 illustrates how the first seven of the response vectors of Fig. 1 also make up a model that fully describes the response of the other devices (in this case, the eighth) from the production run.

The empirical approach not only eliminates the need for detailed design knowledge of the device under test, but also minimizes the number of variables required. For example, the error signatures of many components of a device will be negligibly small and therefore need not be considered. Other components may have signatures that are identical to each other, such as the components of cascaded gain stages. And still others can have error signatures that are different but always track each other.

That last circumstance is common in ICs. A single processing variable, such as dopant level or exposure time during metalization, affects many of the components equally, causing them all to vary in fixed proportion.

MIX AND MATCH. Interestingly, it is not only possible, but often desirable; to combine the physical and empirical modeling approaches and benefit from the best features of each.

Perhaps that is best accomplished by starting with the physical parameters that are known to be important and are perhaps trimmable. It is often rather simple to compute the sensitivity to those parameters, even when the overall circuit is unknown.

Next, the sensitivity matrix of the physical model is augmented with empirical vectors. The result will be a model that can be useful, not only for making accurate predictions, but also for estimating the actual values of critical parameters, which can then be trimmed to achieve compliance.

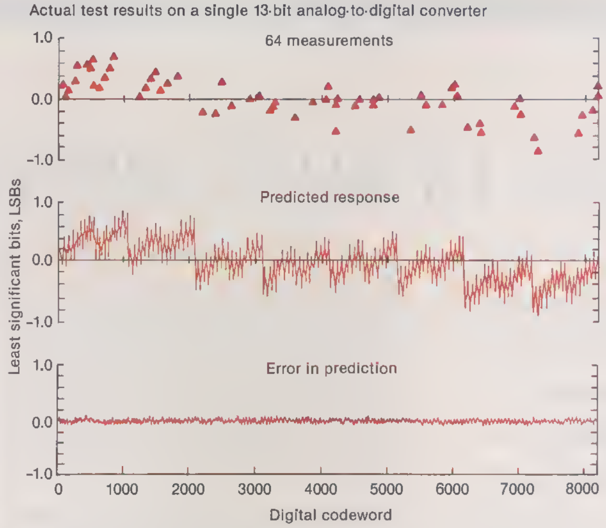
One trial NIST testing program performed in collaboration with Teradyne Inc., a manufacturer of automatic test equipment for the analog and mixed-signal IC industry, combined QR factorization and physical plus empirical modeling. The test was applied to the measurement of integral nonlinearity (INL) for a batch of 127 commercial 13-bit ADCs, all of the same model type. As indicated in our earlier example, the common industry practice for determining the INL of an ADC is exhaustive testing—measuring each of the possible code states to determine the largest error. Even using the fastest available test equipment, that practice adds US $1 or more to the cost of a part that typically sells for only $15. No wonder the industry is looking for a less expensive testing methodology.

For the NIST-Teradyne study, an 18-parameter model of the 13-bit ADC was developed using a combination of physical and empirical modeling techniques. The empirical modeling was based on exhaustive test data obtained from the first 50 devices, which revealed that an 18-vector model sufficed to represent the error space with suitable accuracy. Using that model, 18 test points were chosen, and 46 others were added to obtain redundancy—a total of 64 test points.

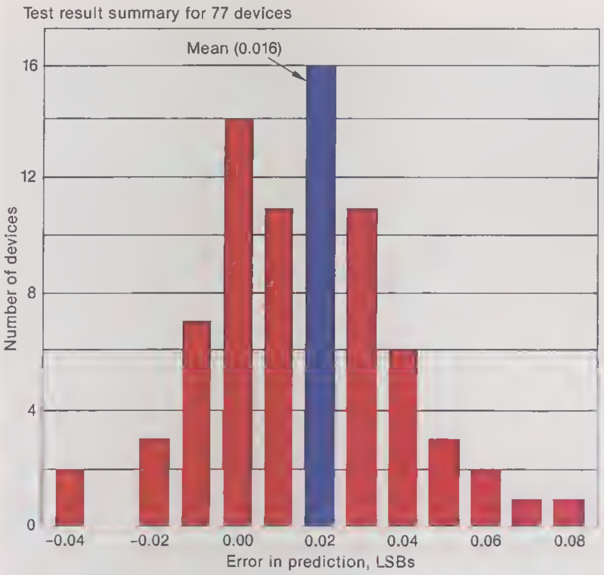
IT WORKS! Measurements at only those 64 (out of a possible 8192) test points were used to predict the overall response of each of the remaining 77 devices. To evaluate the success of the method, the predictions were compared with the results obtained from exhaustive testing [Fig. 4]. The root-mean-square value of the differences was 0.024 least-significant bit (0.0003 percent of full scale), where one LSB is 2^{-13} (0.012 percent of full scale).

Converters such as these are typically sorted according to their maximum INL. The error in predicting that for the 77 devices was also computed [Fig. 5]. (A positive error indicates the predicted maximum is smaller than the measured maximum.) For comparison, the effective noise level in the measurement process obtained by taking the standard deviation of repeated measurements of the same device, was 0.02 LSB.

Since the standard deviation of the predictions is not much greater than that of the measurements, and both are very small, the sorting error rate based on the limited, 64-point test would be similar to that achieved using conventional all-codes testing involving 8192 measurements. With an array processor to speed up the computations, the computational overhead can be kept below 1 second per device. So the test time, which is reduced by a factor of 128, becomes negligible.



[4] Modeling works, as these results for a single analog-to-digital converter make clear. The top plot shows the integral nonlinearity measured at the 64 selected codes. The middle plot gives the predicted errors at all 8192 codes based on the 64 measurements, while the bottom plot gives the error in the predictions—the difference between the measured errors and the predicted errors at all codes. Vertical scales are in least-significant bits.



[5] The value of the new approach is best illustrated by this histogram, which illustrates the differences between the measured and predicted maximum integral nonlinearity for the 77 devices tested. For comparison, the standard deviation of the measurement process—the repeatability of each measurement—is 0.02 least-significant bit.

TO PROBE FURTHER. Various facets of analog and mixed-signal testing strategy have been discussed by the authors and their colleagues. Good surveys of the work are: G.N. Stenbakken and T.M. Souders, "Test Point Selection and Testability Measures Via QR Factorization of Linear Models," *IEEE Transactions on Instrumentation and Measurement*, Vol. IM-36, No. 2, June 1987; and T. M. Souders and G. N. Stenbakken, "A Comprehensive Approach for Modeling and Testing Analog and Mixed-Signal Devices," in the *1990 Proceedings of the International Test Conference*, IEEE Computer Society Press, Los Alamitos, Calif., September 1990.

A three-day workshop is being offered on April 2-4 at the National Institute of Standards and Technology (NIST), Gaithersburg, Md., to provide more in-depth training in the techniques discussed in this article. For more information, call NIST, 301-975-2406.

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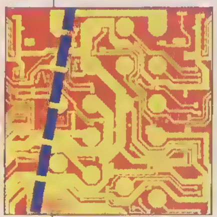
Anatomy of an X terminal

Based on a client/server model, an open, vendor-independent standard offers much flexibility on a local-area network



Not too long ago, a software engineer working on a complex project (such as a device driver or a high-level application) had to switch among different editing sessions to access all the files needed. This information resided on different hosts connected in some type of network and was generally displayed on a character-cell-based ASCII terminal.

That setup is giving way to an environment in which several computer resources can be called up concurrently over an open, distributed network that embraces an entire enterprise. The X Window System is an open, vendor-neutral standard based on the client/server model. This model permits physically independent application processing and display processing, communicating over a local-area network by means of a well-defined set of graphics commands that comprise the X protocol.

X terminals' Graphical User Interface (GUI) [Fig. 1] improves significantly on the ASCII terminal interface. While ASCII terminals usually support only one character font and only one or two windows per display, X terminals can support any number of windows with any type of font or window size. Also, the X terminals' bit-mapped screen allows the application to display all sorts of data formats (text, images, drawings, and so on) simultaneously, enhancing the user's productivity. Finally, since X terminals are diskless, the user does not have to serve as a system administrator; yet the human interface is such that the user feels as if he or she is working at a very powerful workstation.

In fact, in hardware terms, an X terminal is like a workstation that is diskless: it therefore lacks such features as high-speed disk controllers, large caches, and memory management units that are needed in workstations with disk storage. The focus is instead on network communications, graphics performance, and graphical user interface enhancements, and the end result might be viewed as an "application-specific workstation," in the sense that its hardware and software are optimized for running the X protocol.

Because of this dedication, X terminals are generally 40–50 percent more cost-effective than workstations for running X. For example, the IPC color workstation from Sun Microsystems Inc., Mountain View, Calif., clearly a cost-effective Unix workstation, retails for US $8995, while NCR Corp.'s XL-17c X terminal retails for $4470. Similarly, Sun's XLC monochrome workstation retails for $4995, while the 15b unit from Network Computing Devices Inc., Mountain View, Calif., is sold for under $1600.

HUMAN FACTORS. Many factors affecting the human interface are considered in the design of an X terminal. The display monitor should limit eyestrain. The monitor's footprint determines how the unit can be positioned in the work environment. The keyboard and mouse should feel comfortable to the touch. The goal is to make an X terminal easy to use for extended periods of time.

The design of the display monitor should above all minimize visual fatigue. The average human eye detects noticeable flicker at a frequency of 60 hertz, so a vertical refresh rate of greater than 70 Hz is recommended. In the past, a 60-Hz vertical refresh rate was used to achieve a frequency which would minimize aliasing. However, 60 Hz still registers as flicker on most people's peripheral vision (look away from the center of a monitor at about a 30-degree angle, and the screen will seem to flicker to a degree that depends on the persistence of the phosphor it uses and the age of the viewer).

Pincushion distortion and lack of focus quality can strain the eyes also. Although pincushioning is most noticeable as a bulging at the sides or top and bottom of a screen (making it look like a pincushion), it distorts everything displayed. Focus quality should be judged across the entire display; a poor-quality monitor may be in focus in the center, but not on the edges or corners. The eyes' attempt to compensate for distortion and poor focus tends to strain them.

Other ergonomic factors that enhance a user interface are overall display resolution and display size. As resolution increases, so does the amount of information an operator can view simultaneously. If the resolution is held constant, increasing the display size makes text appear larger by decreasing the dot-per-inch density, which may be desirable to some users.

Generally, X terminals come in two cabinet styles, with the logic unit either integrated with the monitor or resident in a separate base, which in most cases can support the monitor. There are advantages and disadvantages with each cabinet style. With a modular cabinet, an X terminal vendor may let the user choose the monitor he or she prefers, or even use a monitor that he or she already has. A modular cabinet may also be placed in an out-of-the-way location, such as under a desk. On the other hand, an integrated cabinet generally provides a lower-cost solution (compared to a modular cabinet unit and monitor of the same size and resolution) because it can use dc power from the monitor rather than requiring its own power supply.

COMMUNICATIONS. Since the X Window System protocol is implemented for a client/server architecture, a great deal of data often travels between the client (typically running on the host) and the server (typically running on the X terminal). Because of the interactive nature of the X terminal application and the volume of traffic that must move between the two machines, traditional RS-232C style communication is not always good enough for the X protocol.

RS-232C serves today's ASCII terminal, which some see being replaced by the X terminal. After all, like an ASCII terminal, an X terminal can be designed to receive VT100, VT220, and/or 3270 style commands from a host using a non-X Teletype-network mode and port. However, in X mode, the

Defining terms

Content-addressable memory (CAM): also known as associative memory, a memory with comparators on each cell to allow a parallel comparison of the input data with all the memory contents.

Point-to-point protocol (PPP): a variation of the serial line internet protocol (which see) that minimizes the amount of data sent by removing redundant protocol information from sequential data packets.

Serial line internet protocol (SLIP): a variation of Ethernet's TCP/IP (short for transmission control protocol/internet protocol) used in X terminals to let them transmit data packets and access several hosts through an RS-232C serial communication line.

Simple network management protocol (SNMP): an application-level protocol that allows logically remote users to inspect and alter network-management variables.

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terminal must in addition be able to pass bit-mapped images, window management commands, and pointer information between the server and the client using the X protocol.

X terminal vendors approach the RS-232C scenario differently. Some design the terminal as if it had to rely solely on RS-232C as the communication link and therefore reduce traffic between the host and the terminal. These vendors accordingly split the server software—the X server—to run on the host and on the terminal [Fig. 2], a redistribution of terminal resources that also lowers terminal cost. Then, by using data compression and a proprietary protocol, they reduce traffic over the serial link enough to get acceptable performance for some applications using a 19.2-kilobaud, or faster, link. The major drawback of this architecture is that vendor-specific software must be ported to each X terminal's host, since a nonstandard protocol, rather than the standard X protocol, is traveling the link.

Since X Windows demands support for multiple simultaneous windows, vendors of RS-232C-based X terminals implement internet style protocols such as TCP/IP over SLIP [see Defining Terms]. Two or more hosts may then communicate with a single terminal, but at 19.2 kBd the performance is quite poor.

A higher-performing protocol that is becoming popular among RS-232C users is PPP. Point-to-point protocol, to spell it out, reduces the amount of information transmitted by "compressing" the TCP and IP header information, making a 19.2-kBd system quite usable. Few hosts currently support this protocol, though.

Other vendors provide RS-232C in addition to some preferred high-speed network link, but the RS-232C port is not used for the X protocol. Thus, an RS-232C printer can also be connected to the terminal for local screen dumps or to provide printing services to other local-area network (LAN) users. Also, since an ASCII terminal is often required for workstation consoles, the RS-232C port can be used to provide a "console window" on the X terminal display.

Most of the first-generation X terminals used 8- or 16-bit controllers as part of their Ethernet interface. The interface chip sets usually consisted of three components—a controller, a Manchester encoder/decoder, and a transceiver. Second-generation X terminals are employing 32-bit Ethernet controllers that not only have a wider data path, but are available with the Manchester encoder and, possibly, the transceiver and other discrete components on a single substrate. This reduces the component count, board space, and power consumption. The designers of 32-bit Ethernet controllers have also reduced the amount of intervention necessary for the system processor to handle Ethernet traffic.

The network management capability of the parts has also been enhanced. Much of the information that is vital to network management protocols, such as the simple network management protocol (SNMP), is now directly available from the Ethernet hardware. In the past, most of this information had to be tracked in software. Content-addressable memory is also beginning to be offered for applications where high-speed broadcasting to select network nodes (multicasting) is important, as on DECnet.

GROUNDING IN GRAPHICS. Graphics depends heavily on memory architecture. For an idea of its importance, consider how X terminals display information—in a bit-mapped fashion on a cathode-ray tube.

A typical display consists of 1024 horizontal picture elements (or pixels) by 800 vertical elements, or approximately 800 000 pixels. All the pixels need to be re-displayed 70 times per second.

For every pixel location on the screen, there is a bit or set of bits in memory: 1 bit for a monochrome display, anywhere from 4 to 8 bits for color. Grayscale displays require 2 to 4 bits to support 4 or 16 levels, respectively, of gray tones ranging from black to white. The display information is stored in an area of memory that is called the frame buffer because the data for the next screen to be displayed is stored in it while the current frame is displayed.

To implement a frame buffer in hardware, the most cost-effective approach (especially for monochrome systems) is to use a section of the terminal's main memory as a buffer and periodically copy its contents into a 256-bit serializer. The serializer outputs the pixel stream serially at the pixel scanning frequency.

There is one major drawback, however. Since standard dynamic RAMs (DRAMs) have only one access port, a certain percentage of bus time must be used for loading the serializer, preventing the system processor from updating the frame buffer. This might not hamper single-bit-per-pixel monochrome displays or systems with big write-through caches, but it becomes prohibitive in multibit-per-pixel systems [Fig. 3].

Today's most popular frame buffer implementation uses a fairly recent innovation in memory chip design called video memory, or VRAM. In addition to a DRAM, a VRAM contains an n-bit-long shift register that can be loaded in parallel from the DRAM's n sense amplifiers and output data through its own serial output port—hence the other name for this type of memory, dual-ported RAM. This data can be shifted out of the register without using the random access port or taking up bus bandwidth. The shift register in the VRAM is used as a serializer to refresh the display. When it empties, the processor performs a transfer cycle and reloads the shift register with new data—the only overhead for VRAMs.

Since the VRAM allows the processor to utilize the random access port more efficiently, it provides faster graphics performance. However, this added performance is not free. For the same memory density, prices of VRAMs are about twice as high as for DRAMs. Still, for color and gray-scale applications, VRAMs make the most sense.

Another important use of memory X terminals is for look-up tables. For displays, a look-up table can be thought of as a way

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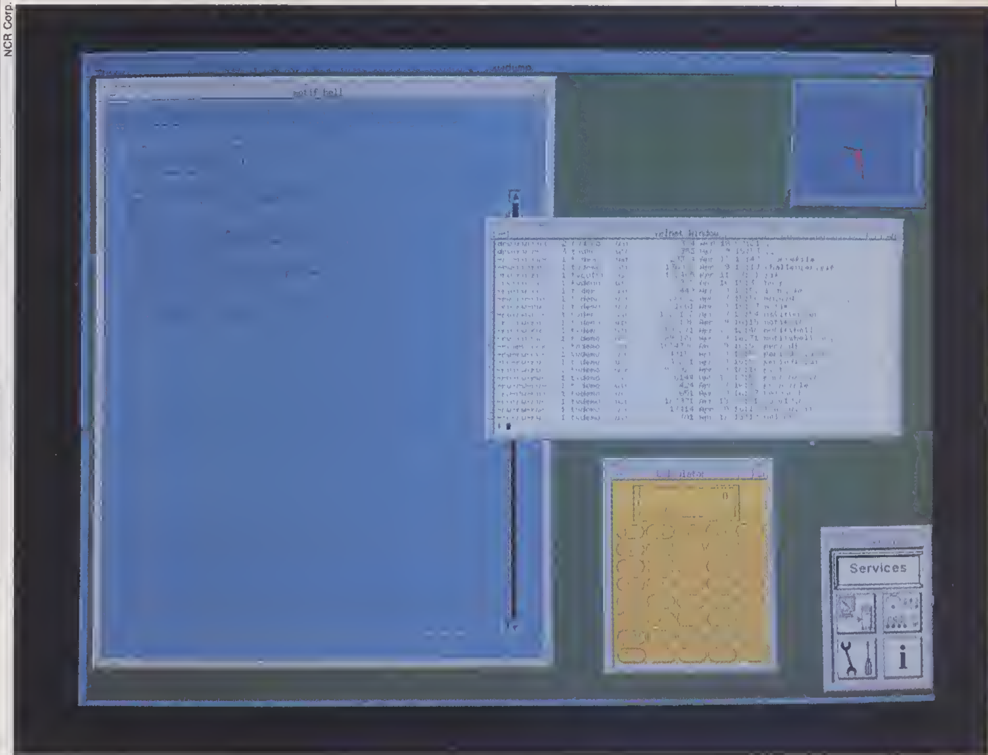
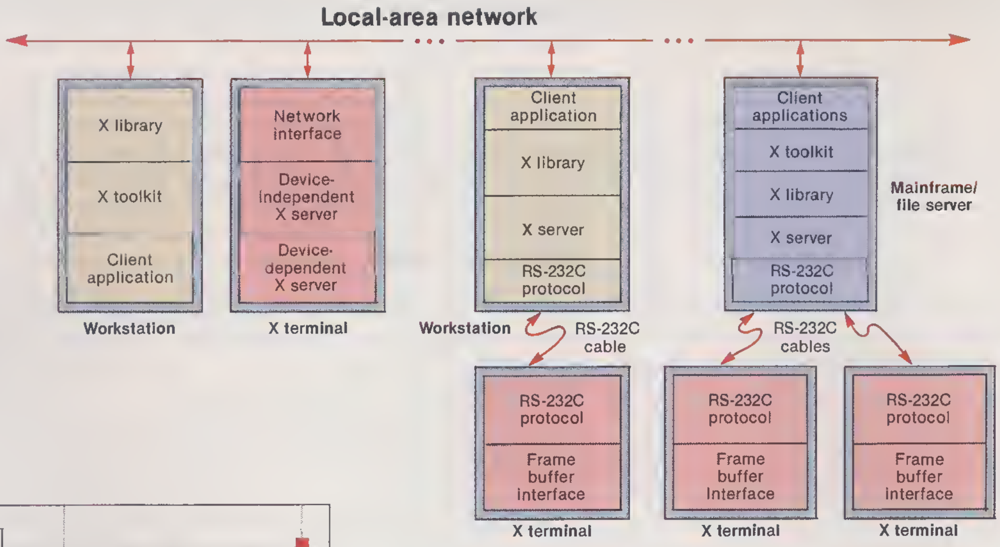
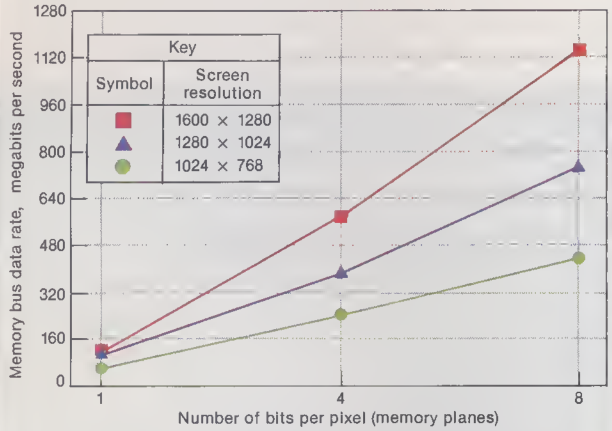


[1] X terminals' ability to handle multiple windows and mouse commands calls for more elaborate hardware than was needed by their predecessor, the ASCII computer terminal.



[2] X terminals fit into today's networked environments in several different ways: connected directly to the local-area network, or linked to a workstation or other host with an RS-232C serial interface. The way they are used affects not only their interface hardware but their software requirements as well.



[3] With a dynamic RAM frame buffer, display size and the bits per pixel determine memory bus performance requirements. Monochrome (1 bit per pixel) does not have much impact, but high-resolution color (8 bits per pixel) demands a very fast bus.

Some color X terminals

Product	Company	Resolution, picture elements (W × H)	Screen diagonal, inches	Price, U.S. $
View Station 21c	Human Designed Systems Inc.*	1280 × 1024	21	$6999
Xstation 120/6091	IBM Corp.		19	$9686
XP29	Tektronix Inc.		19	$5995
17c	Network Computing Devices Inc.		17	$5000
XL3412 17C	NCR Corp.	1024 × 768	17	$4800
700/X	Hewlett-Packard Co.		16	$4995

Source: Dataquest Inc. * King of Prussia, Pa.

of mapping a set of predefined values to different domains having either a different number of elements or more information content. Its most common application is to increase the number of displayable colors without increasing the number of bits per pixel.

A color display with n bits per pixel that does not use a look-up table can display only 2^n colors at a given time. The n bits select a value for the red, green, and blue components of each pixel in the color display, maybe $n/3$ bits for each of the three electron-beam colors (red, blue, and green). For instance, a 6-bit-per-pixel display could assign 2 bits to each of the three color elements, which would result in a range of four shades per color element. In combination, the four shades per element result in 64 possible colors.

The use of a look-up table, however, yields a larger range of combinations. The table employs the number represented by all n bits as an index to a table of values m bits wide. The total number of colors is now a function of m and not n. That is, any 2^n subset of 2^m colors can be displayed. For example, a 16-bit-wide look-up table can contain what is commonly referred to as a color palette of over 64 000 colors. At 6 bits per pixel, 64 colors can be selected from the palette and displayed on screen at any instant.

CURSORY NOTES. The X terminal GUI specifies a cursor block directly controlled by the mouse. Since multiple windows can reside in the same display, the cursor is used as a pointing device to the window being worked on. The simplest way of implementing the cursor block is for it to be painted on the screen by the display processor when the electron beam reaches the right scan line, and then removed after the beam has passed. One way of implementing this would be to have a timer interrupt the processor before and after the electron beam passes through the cursor area. For example, Texas Instruments Inc., Dallas, builds this interrupt feature into its TMS34010 and TMS34020 graphics processors.

When the interrupt is sensed, the display processor performs a block transfer of the cursor information into and out of the display area—to the detriment of the terminal's overall graphics performance, however.

An alternative is to implement the cursor completely or partially in hardware, unburdening the processor and resulting in better overall performance. Thus some color X terminals drive their displays with a video controller and color palette combination that have, or make it possible to add, cursor logic. For example, the Bt459 from Brooktree Corp. in San Diego, Calif., provides a 64 × 64 cursor block. Some other of the RAM-plus-digital-to-analog-converter devices like the Bt458 provide several overlay inputs to help implement a cursor block externally. All of these devices have built-in look-up tables that modify the display information when the cursor block is being displayed.

OPTIMIZED DRAWING. To achieve the best performance possible in X terminals, vendors will spend time optimizing drawing operations as well as the upper layers of the X server. Hardware may be used to support the lowest level of graphics primitives, with lengthy operations (such as primitives that move windows) being prime candidates for optimization. Hardware interfaces that work in conjunction with the microprocessor during the drawing operations are used by some vendors like Network Computing Devices and Datacube Inc. in Peabody, Mass. Other vendors, like IBM Corp., Hewlett-Packard Co., and NCR Corp., use dual processors

to split the workload of rendering, X server, and communications overhead. Both methods have advantages.

Some X terminals use graphics assist methods to boost the performance of drawing operations such as a bit block transfer, also known as bitblt. A bitblt can be defined as a logical operation performed on bit-wise boundaries between source and destination regions; an example is the movement of a window from one position to another on the screen.

The graphics assist logic is an interface to the frame buffer and system memory. This interface—which handles barrel shifting for bit alignment, concatenation of data, and preprogrammed logical operations—"assists" the processor by letting it act merely as a two-dimensional direct-memory-access controller for the graphics assist interface. This can double the inner loop performance of the bitblt operation.

Some X terminals in the market today have two processors—a system CPU and a graphics processor—with which a certain level of parallelism can be achieved. For instance, in one approach, the system processor supports the communications and handles system interrupts, while the graphics processor runs the X server and handles the drawing operations. Some parallelism occurs here because the CPU can process TCP/IP packets for future operations while the X server running on the graphics processor finishes past operations.

Other vendors make the system processor responsible for communications and the top layers of the X server (where event handling and region clipping is performed), passing only drawing commands to the graphics processor. Parallelism can occur here because the X server can process several commands while the graphics processor is drawing previous operations.

As an example of how parallelism can be used in multiple-processor X terminals, suppose an engineer is running a computer-aided design (CAD) application and a series of lines and text representing a schematic is displayed. The application displays a button labeled "redraw." When the button is "pressed" (by using the mouse), the following events may occur:

- The button press is processed and passed to the application.
- The application recognizes the event by highlighting the button.
- It clears the CAD drawing area.
- It recreates a list of graphics primitives to redraw.
- It sends the list to the X terminal.
- It unhighlights the redraw button.

Here, the first event is initiated by the X server, while the others are initiated by the CAD application on the host.

The fifth event gives the best example of how parallelism can be used. As the list of graphics primitives arrives at the X terminal (in one or more packets), the portion of the X server running on the system processor can clip the primitives and place them one by one into a drawing queue. While the system processor builds this queue, the graphics processor can asynchronously draw the screen using the commands taken from the queue. Obviously, parallelism can significantly improve X terminal performance.

RATING PERFORMANCE. Crucial here is the terminal's response time; a user does not want to sit in front of a terminal for 5 seconds waiting for a page to be painted or a Unix session to start. Total response time is affected by network bandwidth and utilization, host performance and loading, X server implementation, and graphics rendering performance.

There have been a few attempts at rating terminal performance. The most popular is a test suite developed by Claus Gittinger from Siemens GmbH, headquartered in Munich. This benchmark, commonly known as Xbench, has the host send a set of graphics commands to the terminal, and measures the time the terminal takes to complete the commands. The tests cover the six most common operations: line drawing, rectangle drawing, bitblts, arcs, text rendering, and complex operations. The output of this benchmark has three forms: absolute performance data from the individual tests, statistics and relative performance data for each test subgroup, and a weighted average of relative performance named "xstones." All the relative performance ratings are based on a direct comparison with the performance of a SUN 3/50 workstation running the X11.3 version of X under OS 3.4.

Another performance bench mark is X11 perf. Made up of 166 tests, it is more comprehensive than X bench but does not give a single rating.

These tests provide a good measure of the X terminal's graphics performance. However, they fail to measure the overall response time of the terminal; that is, the delay from the time a user causes an asynchronous event (by depressing a mouse button, say, or moving a window across the screen) to the time the proper response occurs at the terminal. There are no widely accepted benchmarks for this purpose and, until they arrive, X terminal performance evaluations are limited to the graphics component, perhaps the largest piece of the pie.

> Present tests of X terminals don't measure true performance

MARKET POTENTIAL. X terminals have been bought primarily for engineering design environment applications, such as CAD and computer aided engineering, where they have served as display devices with a lower cost per seat than traditional Unix workstations. Another market that has begun to migrate to X terminals has been manufacturing, with applications such as process control, which requires high-resolution displays.

X terminals have also been used to enhance material requirement planning applications by enabling the user to view multiple text modules from different hosts concurrently and to "copy and paste" among these modules. A number of markets requiring customer servicing applications—such as utilities, airlines, and freight forwarding—are implementing X terminal environments for concurrent viewing of different customer database records.

As X terminals achieve new price performance plateaus, the market is expected to expand to more business applications requiring the network connectivity and multiple viewing of applications that X offers [Table].

TO PROBE FURTHER. A good source on most issues on computer graphics hardware design is *Computer Graphics Hardware: Image Generation and Display* by Hassam K. Reghbati and Anson Lee (IEEE Computer Society Press, Washington, D.C., 1988). *Fundamentals of Interactive Computer Graphics* by J. D. Foley and A. Van Dam (Addison-Wesley, 1982) gives a more general overview of technologies involved in graphics rendering. Another important reference work, now in its second edition (1990) from Digital Press, Bedford, Mass., is *X Window System* by Robert Scheifler and Jim Gettys (who originally proposed the X Window System).

For a detailed understanding of the X Window System, O'Reilly & Associates Inc. offers a nine-volume series called *The Definitive Guides to the X Window System*, now in its second edition (Sebastopol, Calif., September 1990).

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Cooper received his BS and MS in electrical engineering from the University of Florida at Gainesville in 1985 and 1987.

Stonecypher received a BS and MS in electrical engineering from Georgia Institute of Technology in 1986 and 1987. ◆

When bust is best

Wrecking balls, shaker tables, fires, winches—all prove indispensable in the fine art of proving equipment by destroying it

One sunny afternoon in Chester, N.J., several AT&T Bell Laboratories engineers installed a community service cabinet full of electronic communications equipment in a vacant lot, scattered two bales of dry hay around it, and set the hay on fire. They watched as the flames leaped high, blackening the beige finish. But the heat did not melt the solder in the electronics inside, nor did smoke harm them, nor was there any interruption in the simulated telephone service transmitted through the cabinet.

Such arson can be part of the destructive testing programs such as those at AT&T Co., Bell Communications Research Inc. (Bellcore), the Electric Power Research Institute (EPRI), and various laboratories, where engineers "try to find out what's wrong with new equipment before their customers do," remarked Dan Pope, supervisor of AT&T Bell Laboratories' Chester operations. Such labs are "a halfway house between the engineer's mind and the real world."

Destructive testing falls into two basic, although somewhat overlapping, categories. The first is limit testing to the equipment's failure point, to ascertain safety margins and the most extreme conditions under which it will perform its basic functions. The other is environmental testing under real-life conditions, to see how reliably the equipment can withstand the rough handling of transportation, installation, and operation. At times, destructive testing is also used to duplicate the conditions of past accidents, to learn how future ones can be avoided. And some testing—including some environmental testing—may not specifically intend to be destructive but just happens to reveal flaws when the equipment breaks.

Although environmental stress screening for electronic devices and consumer products is well known, it may be surprising to some to discover that all parts of transmission and switching systems go through similar rigors. In fact, whether it is a circuit board or a 70-meter-high transmission tower, the same testing philosophy applies. In addition, many development and test engineers are convinced that, even though the results of the tests often end up in the dumpster, destructive testing is ultimately cheaper than computer simulations—because it more accurately reflects reality.

Trudy E. Bell Senior Editor

STANDARDS FOR ABUSE. Next door to AT&T's Chester destructive testing facility is Bellcore's. Their proximity is a result of the divestiture of the Bell System in 1984, which split the original 400-acre (160-hectare) Chester facility down the middle.

Destructive testing helps Bellcore in one of its prime roles: preparing and proposing generic requirements for the physical protection of communications equipment against the ravages of changing temperature, humidity, contamination, electrostatic discharge, fire, earthquake, lightning, and other factors, said Conrad Spring, the laboratory's division manager of network physical protection at Chester. Also, when one or more Bellcore owners—the seven regional holding companies responsible for local telephone service—show an interest in vendors' or suppliers' equipment, Bellcore will analyze it to see whether it complies with the generic requirements.

> Through destructive testing you sacrifice equipment for reliable information

Chiefly, Spring told *IEEE Spectrum*, Bellcore's relevant generic requirements for physical protection are described in "one fundamental document": Bellcore's Technical Reference 63 (TR63): Network Equipment Building System Generic Equipment Requirements, or NEBS Requirements for short. To a lesser extent, Spring added, manufacturers and communications providers also use environmental requirements outlined by various standards groups, such as the T1 telecommunications committee of the American National Standards Institute (ANSI), New York City.

For example, several standards for fire resistance have been devised by IEEE Committee 383 and the American Society for Testing Materials Committee E5, said Bellcore's John Simpson, district manager for fire protection technology and environmental control in Morristown, N.J. One of the ANSI T1 subgroups, T1Y1.4, is currently working on fire-protection standards for assemblies of equipment—literally a burning issue in telecommunications since the Bell System divestiture admitted new vendors.

Bellcore also uses destructive testing to model and analyze past central office fires, such as the 1988 Hinsdale fire in Chicago or the 1975 fire on New York City's Lower East Side. For example, they ran tests simulating the arcing between power cables, and then compared the rate of ignition and fire spread in older cable that did not satisfy TR63 with what happened in newer cable that did, Spring said. The tests "verified in the most seeing-is-believing way that if the materials meet the TR63 requirements, you don't get the ease of ignition and extent of fire spread" that results from using nonconforming cable, Spring said.

Such tests are monitored by videotape recordings and expert visual observations, as well as thermocouples to measure heat, photoelectric cells to measure smoke obscuration, and ionization detectors to measure the capacity of the smoke to activate alarms.

HORNETS AND PAINT. Bellcore also uses destructive testing to diagnose peculiar problems in the network. Several were introduced, for example, by the substitution of less expensive plastics for expensive metals.

One problem was the cracking of the plastic network interface device boxes (installed on the outer wall of a building where the outside network connects with the customer's inside wiring). The plastic boxes were designed to be rain- and dust-proof, immune to the sun's ultraviolet radiation, and even resistant to impact. But crack they did, letting in moisture that shorted connections.

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The cause of the cracking turned out to be chemical. So that hornets do not launch surprise attacks from within a box, maintenance technicians routinely spray the interior with insecticide before beginning work, explained Donald C. Pote, Bellcore's division manager, apparatus and materials requirements and analyses and quality technology, Morristown, N.J. And many of the commercial insecticides applied eventually cracked or distorted the plastics. In addition, customers painting their buildings would paint the boxes as well, and some of the paints also attacked the plastic. As a result of various environmental tests, Bellcore devised requirements for cabinets to be made of plastics that resisted common chemicals.

FIRE AND ICE. At AT&T's Chester facility next to Bellcore's, engineers "throw equipment in boxes off the back of moving trucks, shoot at cabinets, drive trucks over cables, blow dust at electronics, and leave cardboard boxes full of equipment out in the ice and snow," said Pope—all so they can see how well network equipment will stand up to the rigors of actual transportation and installation. By such deliberate but realistic abuse, "we're able to shake the last-minute bugs out of a product design," he told us.

One of the main problems uncovered by this kind of destructive testing is unexpected flaws in the basic design. For example, in 1985, AT&T design engineers asked Pope and his staff to evaluate an outdoor pedestal terminal, a grey plastic enclosure mounted at ground level where distribution cable from the central office is connected to service wires to residences. The design engineers had developed a plastic cover resembling a bell jar, which would trap a pocket of air to keep the connectors dry during a flood. They wanted to make sure the cover was free of pinholes that would let the air leak out and the water level rise inside. Instead, Pope reported, when the AT&T engineers submerged the pedestal in 4 meters of water simulating a flood, "the fault we actually found was a weak plastic latch," which gave way, so the flood cover "came shooting up like a Poseidon missile."

The AT&T engineers also look for surprises in installation techniques. For instance, in 1983, early in the development of optical-fiber cable, AT&T engineers took some newly designed cable to a Pennsylvania test site between Harrisburg and Carlisle, and experimentally plowed 20 miles (30 kilometers) of it underground using standard techniques for installing copper cable.

When they dug up the fiber cable to examine it, they discovered that individual fibers inside the cable had been broken, even though the sheath was still intact. Analysis and further tests at Chester revealed that the plowshare broke shale in the soil into sharp fragments, which grabbed the cable and locked it "like Velcro" into the ground, said Pope. Then the up-and-down movement of the plowshare produced forces strong enough on the cable to break the fibers. "Our discovery led to a new concept for fiber cable plows," said Pope.

Another purpose of destructive testing is to ascertain what is necessary and practical to make the network resistant to vandals. While in theory cabinets could be made absolutely impervious, the cost of armoring them all like tanks would be prohibitive. So how good is good enough?

The telephone community service cabinets are designed to be opened only with the aid of a special tool. But a Chester engineer demonstrated that a persistent "7 to 10 minutes of karate kicks" or levering with a tire iron could batter the door open, said Pope. That result was satisfactory, as it was deemed "sufficiently discouraging, or the clamor enough to attract the attention of the authorities." Similarly, engineers with rifles have proven the cabinets will withstand being peppered with a .22, but it was deemed too expensive "and perhaps paranoid" to make them resistant to an assault weapon, Pope said.

SHAKE IT UP. At Whippany, N.J., AT&T Bell Laboratories also has an indoor environmental testing laboratory that, among other environmental rigors, simulates vibration that would be encountered in situations ranging from fighter aircraft to earthquakes, said Arthur Drury, a test engineer there.

Document TR63 divides the United States into zones of earthquake risk, ranging from 0 to 4; each zone, calculated from geological history, represents a certain probability of an earthquake as bad as any that has happened historically. Many areas in California, for instance, are designated Zone 4.

To test switches and other central office equipment to see if they can withstand a Zone 4 earthquake, the engineers mount racks of electronics on a hydraulic shaker table, Drury explained. Since most earthquake energy is concentrated at lower frequencies, below 20 hertz, the table's servo-controlled piston has a usable stroke of 10 inches (25 centimeters), which can produce up to 10 times the earth's gravitational acceleration with a frequency as low as 5 Hz. A wave form representing the time history of a typical earthquake, stored on magnetic tape, is used to control the input to the table to produce motion that varies in frequency and intensity, closely duplicating actual vibrations of a major temblor.

AT&T Co.

Ballistic tests with rifles and shotguns are conducted at AT&T's test facility at Chester, N.J., to evaluate the resistance of cabinets for outside plant equipment to onslaught by armed vandals.

To simulate the shock and vibration of moving trucks, planes, ships, tanks, personnel carriers, or other vehicles—as well as airplane crashes and gunfire—equipment is mounted on an electrodynamic shaker table. Driven by an electrodynamic coil (similar to a large voice coil), this table creates higher-frequency vibration with its smaller stroke (1.25 in. or 3 cm) and higher force ratings (up to 100 gravities near 100 Hz).

For experiments using either shaker table, the engineers instrument the equipment's different structural members with piezoelectric accelerometers to measure the dynamic levels encountered, Drury explained. "We may also hook up certain high-priority items, such as a power supply," because of

its heavy transformers, he said. Then, to see clearly what happens every moment, the Whippany engineers watch and film the vibrating rack under stroboscopic light. "The frame may bow enough to deform the card cages and allow the plug-in cards to back out," Drury remarked, "or the chassis may be distorted" in ways that could be mechanically reinforced.

CUSTOM TESTS. The Whippany laboratory has also done specialized destructive tests prescribed by military standards for AT&T's defense customers. One is the high-impact shock test for lightweight electronic equipment specified by MIL S-901-C, simulating either a collision aboard Navy ships or the blast effect from mines certain distances away, Drury recounted. In this case, a 400-pound (180-kilogram) concrete block measuring 4 by 1 by 2.5 feet (1.2 by 0.3 by 0.8 meter) on the end of a steel I-beam 5 ft long hung in a 16-ft frame. Like a wrecking ball, it is allowed to swing from heights of 1, 3, and 5 ft into the back of a steel support plate on which the items are mounted. If the equipment is still in one piece and working at the end of each test, it passes.

When no standard exists for a new piece of equipment, the Whippany engineers may be called to devise a realistic test. Once AT&T design engineers working on classified equipment (which Drury described only as a "military device for optical communications" containing lenses and prisms in oil) requested that Drury and his colleagues put it through some thermal cycling. They wanted to duplicate the temperature changes between the storage room on board ship and the subfreezing temperatures under the ocean, where it would be operating. The design engineers hypothesized that a couple of days' cycling between half an hour's exposure to each temperature extreme would do the job. "We advised the design engineers that there was so much mass involved that half an hour's soak at each extreme would not influence the temperature inside," Drury said. In fact, thermocouples revealed that 11 hours at each temperature extreme was necessary.

The design engineers assented. The equipment was put into a chamber and alternately baked and frozen. The thermal cycling revealed that an epoxy "did not have sufficient compliance at the low temperatures, and cracked a costly lens" several inches in diameter—a problem that "would not have been found if it had not been tested" so realistically, Drury observed.

GOING FOR BREAKDOWN. One organization testing electric power transmission systems in the United States is EPRI. "You don't have an accurate data point unless you have a failure," declared Ralph Samm, program manager of underground transmission, at EPRI's headquarters in Palo Alto, Calif. "You don't know how good a power cable actually is until you know where it will break down." Samm and his colleagues simulate lightning strikes and switching surges on power cables at the EHV (Extra High Voltage) Cable Test Laboratory in Yonkers, N.Y.

With the lightning test, for example, as described by IEEE STD-4, a cable is hit with an impulse of a standard wave shape, whose voltage rises from zero to its maximum in 1.5 microseconds, and takes 50 μs to return to half of the peak value. "We bang away at it with higher and higher voltages until an arc burns a hole" through the dielectric between the inner conductor and the outer ground shield, said Samm. This provides the data point that helps determine the safety margin in a newly designed cable. "We try to take it to failure, although in some systems that's not possible," Samm said, since an arc may flash over to the termination point before the cable itself breaks down.

AT&T Co.

An AT&T Co. 80-type community service cabinet housing communications equipment was surrounded by hay that was set on fire to test its durability through grass fires. Simulated telephone service through the cabinet was not interrupted during the test.

Electric Power Research Institute

Transmission tower for the Western Area Power Administration was tested to failure at the Transmission Line Mechanical Research Center of the Electric Power Research Institute (EPRI). The heavy transverse loading exerted by the winches simulated high winds blowing against an ice-covered conductor.

Bellcore

An earthquake simulator at Bell Communications Research Inc. (Bellcore) varies the intensity of its shaking to simulate tremors from a small-scale quake to the really "big one." Here technicians, planning for the totally electronic central office, test the structural durability of equipment on a raised floor.

Transmission line towers also come in for their share of abuse at EPRI's Transmission Line Mechanical Research Center (TLMRC) in Haslet, Texas. There, tests are conducted to evaluate their structural response to static loads due to wind or ice on conductors; dynamic loads from broken wires, dropping ice, or wind-induced oscillations; and twisting produced by unbalanced loads on the extremities of the structure's cross arms. The center's data-processing facility also enables engineers to predict a failure and to work out design modifications.

Transmission structures are designed using many industry guidelines from the American Society of Civil Engineers, ANSI (the National Electric Safety Code ANSI C-2), the International Electrotechnical Commission, and the IEEE. Data from tests conducted at facilities such as the TLMRC are instrumental in updating and enhancing those guidelines, according to Richard Kennon, EPRI's senior program manager of overhead transmission lines.

He noted that the center's pair of reinforced concrete test pads can support and mechanically load all types of individual transmission structures. Its 2-mile (3-kilometer) test line right-of-way also allows EPRI's member utilities to test structures as components of complete line systems.

ALL FALL DOWN. Five steel reaction frames looking somewhat like cranes are rigged with cables and winches with continuously controllable dc motors that apply loads to the test structure. Each frame, which is 240 ft (70 meters) high, can be moved on guides to optimize its location for each test. Up to 40 winches can be used for a single test, with the rigging from each one instrumented to indicate the applied load and provide feedback to the load control system.

Software running on a test computer system controls the loading while monitoring all loads several times a second, compares the data with the preprogrammed load agenda, and determines whether a test can safely continue. A color cathode-ray tube (CRT) provides simultaneous real-time readouts of all loads and winch parameters, allowing the operator to monitor the test while also viewing it through a window.

Resistance-type strain gauges measure the stress in individual structural members, whether the overall load is vertical (as if due to ice), horizontal transverse to the line (as if due to wind), or horizontal in the longitudinal direction (as if due to broken conductor or unbalanced ice). In each case, the loads are simulated by the pull of cables connected to computer-controlled winches. Remote-controlled still, movie, and video cameras also monitor each test.

One of the most dramatic tests was conducted last year for the Western Area Power Administration, Golden, Colo., on a 500-kilovolt single-circuit tangent tower. The tower consisted of a 110-ft (34-meter) body atop a 40-ft body extension and 40-ft leg extensions. The loading simulated heavy transverse wind against ice on the conductors and tower. As expected, the destructive test revealed that the compression legs in the leg extensions would buckle. The structure then shifted transversely, causing the body extension to fold back and forth accordion-style until only the 110-ft body was left standing. While the failure was expected, the extent of the damage was not.

Some standards for destructive tests of power and communication transmission equipment

Name of standard	Sponsor	Description
Technical Reference 63: Network Equipment-Building System (NEBS) Generic Equipment Requirements, 1988	Bell Communications Research Inc., District Manager, Information Exchange Management, 435 South St., Room 2K122, Morristown, N.J. 07960-1961	Generic requirements for the physical protection of telephone equipment against fire, earthquake, chemicals, temperature, humidity, electrostatic discharge, lightning, and so on
National Electric Safety Code ANSI C-2, 1990	IEEE Standards Office, 445 Hoes Lane, Piscataway, N.J. 08855-1331	Defines the loads (wind, tension, and so on) power transmission towers must withstand
MIL-STD-810E: Environmental Test Methods and Engineering Guidelines, 1990 (Notice 1)	Aeronautical Services Division, attn: ENFSL, Wright-Patterson Air Force Base, Ohio 45433-6503	Army/Navy/Air Force document for testing military electronic equipment assemblies for climatics (such as temperature, altitude, and humidity) and dynamics (shock, vibration, and acoustics)
MIL-STD-883C: Test Methods and Procedures for Microelectronics, 1985 (Notice 4)	Commander, Rome Air Development Center, AFSC, attn: RSE-2, Griffiss Air Force Base, N.Y. 13441	Army/Navy/Air Force/National Aeronautics and Space Administration document for testing military electronic parts for temperature cycling, temperature shock, centrifuge, dynamic shock, vibration, bond pulling, and so on

Source: Alison Boulter, product manager, industry standards, Information Handling Services Inc., Englewood, Colo.; Henry (Hank) Caruso, fellow engineer, environmental simulation engineering, Westinghouse Electric Corp., Baltimore, Md.; Vince Condello, staff engineer, IEEE Standards, Piscataway, N.J.; Conrad Spring, division manager, network physical protection, Bellcore, Research, Morristown, N.J.
Note: some of the tests are not necessarily intended to be destructive, but they could result in equipment damage.

IMPERFECT ASSUMPTIONS. But why resort to destructive testing when software simulations would be cheaper, especially since electrical and communication transmission equipment is so big? Conversely, since a fair share of the data gathered during destructive testing is qualitative rather than quantitative—making certain techniques as much an art as a science—what do engineers learn in the field that cannot be effectively duplicated in the lab?

While people may have "the dream of doing away with real-life testing, that dream has not come true yet," said EPRI's Kennon. Lattice structures such as transmission towers, loading forces such as wind and ice, and abrupt movements such as the twang of a breaking cable "are too complex to be accurately analyzed given our current software tools," which may have simplified assumptions that do not match well with reality, Kennon said. The only way of verifying assumptions is to test them in the real world.

The mismatch between complex reality and simplified assumptions came to the TLMRC's attention when the center took the specifications for a U.S. utility's tower and gave the design to 20 eminent designers around the world; they explained that certain forces would be applied, pulling on the tower in certain directions. The center asked the designers to analyze the resultant effects on the structural members.

"The answers varied over a range of 2 to 1," Kennon said. When the EPRI engineers actually tested the tower, the real performance turned out to be "pretty close to the average" of the 20 analyses, Kennon said.

IMPROVING MODELS. One reason is the different assumptions made by various computer models to simplify the complex calculations. For example, Kennon noted, most general-purpose finite-element-analysis software assumes that tension-only members—such as the thin, diagonal cross braces that stiffen a lattice structure against lateral forces—support no compression, as if they were constructed of rope or string. In real life, however, tension-only members do offer non-negligible support in compression, causing unexpected stresses throughout the structure. Said Kennon, "We are developing a tension-only element modification for finite-element analysis software," one of 17 modifications used in computer models, based on test results from the TLMRC, that will make their assumptions more realistic.

Thus, destructive testing not only tests structures, but can also improve computer models. "There are times when you should complete a test to destruction, to prove out your ability to predict failure," said Kennon.

"The real world can't be modeled exactly, so people make assumptions," said AT&T's Drury. "And often Mother Nature finds fault with our assumptions." While computer modeling is highly useful, designs must always be tested and verified; otherwise engineers are "tempting fate," he said. He added: "Would you like to fly in an aircraft that had been only modeled and never flown?"

TO PROBE FURTHER. For life testing of individual electronic components, see "Recipe for reliability: shake and bake," by Wayne Tustin, *IEEE Spectrum*, December 1986, pp. 37-42. For an account of the May 1988 electrical fire in the telephone switching station in Hinsdale, Ill., see "Keeping the phone lines open," by Glenn Zorpette, *Spectrum*, June 1989, pp. 32-36. ◆

Behind the Laplace transform

Back to basics

Generations of electrical engineers have valued this transform as a fast route to finding the transient as well as the steady-state outputs of circuits having aperiodic as well as periodic inputs

The Laplace transform is perhaps *the* mathematical signature of the electrical engineer, having a long history of application to problems of electrical engineering. It changes some of the most important differential equations of physics into algebraic equations, which are generally far easier to solve.

Despite its Gallic name, the transform originates with the Swiss mathematician, Leonhard Euler (1707–1783), who in 1744 wrote integrals that look much like the modern version. These were adapted by the Italian-French mathematical physicist Joseph Louis Lagrange (1736–1813) to the needs of probability theory, and his work in turn influenced the Frenchman Pierre Simon Laplace (1749–1827).

By 1785 Laplace was writing the almost modern Laplace transform [Equation 1, blackboard]. Today it is still used, as the Mellin transform, to solve certain differential equations with variable coefficients. But an electrical engineer would write it differently [Equation 2, blackboard].

Then in 1807 Laplace's fellow-countryman, Joseph Fourier, published the first monograph describing the heat diffusion equation. Intrigued, Laplace tried his hand at solving it, obtaining results that in turn inspired Fourier's discovery of his own transform.

The connection between the Fourier transform (used by EEs to study the power and energy spectra of signals) and the Laplace transform is intimate, but they are not equivalent. For example, the step function has a Laplace transform, but not a Fourier transform. And while the Fourier transform is useful in finding the steady-state output of a linear circuit in response to a periodic input, the Laplace transform can provide both the steady-state *and* transient responses for periodic *and* aperiodic inputs.

For the modern EE, the lure of the Laplace transform is its ability to map the complicated operation of convolution into multiplication. This integral has for decades driven electrical engineering undergraduates to contemplate theology either for salvation or as an alternative career. The equation states that if $x(t)$ is the input to a linear system with impulse response $h(t)$, then the output, $y(t)$, is $x(t)$ convolved with $h(t)$ [Equation 3, blackboard]. But if $Y(s)$ and $X(s)$ are the associated Laplace transforms, this imposing integral is completely tamed [Equation 4, blackboard].

In one of those astonishing coincidences that could mean mathematics is not just a game of made-up rules, the convolution integral also plays a central role in the theory of random variables: if $x(t)$ and $h(t)$ are the probability density functions (pdfs) of two independent random variables, X and H, then the pdf, $y(t)$, of $Y = X + H$ is found by convolving the pdfs of X and H. The Laplace transform consequently sees a lot of use in probability theory, where Laplace first found it.

Over a century had to elapse, though, before these sophisticated applications of the Laplace transform could evolve from the form in which Laplace left it in 1827. For EEs, the next big advance was made by the eccentric Englishman Oliver Heaviside (1850–1925). He reduced differential equations directly to algebra by representing time differentiation as an operator. He used p, as in $px = dx/dt$ and $p^2x = d^2x/dt^2$, while $1/p\,(x)$ = the integral of $x\,dt$, and then manipulated these equations using any algebraic trick he could think of, including his famous Heaviside expansion theorem, which is essentially the partial fraction expansion of modern Laplace theory.

$$y(s) = \int_0^\infty t^s\, y(t)\, dt \qquad (1)$$

$$Y(s) = \int_0^\infty e^{-st}\, y(t)\, dt \qquad (2)$$

$$y(t) = \int_0^\infty h(u)\, x(t-u)\, du \qquad (3)$$

$$Y(s) = H(s)\, X(s) \qquad (4)$$

But Heaviside was notoriously unconcerned with rigor. For instance, he never blinked an eye when *fractional* operators, such as $p^{1/2}$, arose. This lofty attitude of his greatly delayed acceptance of his work, even though fractional operators were already old news in mathematics.

Before he died, Heaviside exchanged several letters with mathematician Thomas John I'Anson Bromwich (1875–1929) of Cambridge University in England. Bromwich established the missing rigor by showing how to interpret Heaviside's work in terms of complex, Laplace-like integrals; but his suicide in 1929, before he could promulgate these new ideas, probably accounts for his anonymity among EEs today.

Until the end of the 1930s, the more advanced EEs continued to use Heaviside's *ad hoc* techniques. But lesser analysts were all too often swallowed up in the dangers of methods a master like Heaviside could intuitively sense and sidestep.

Then, in 1937, the German mathematician Gustav Doetsch published his book *Theorie und Anwendung der Laplace-Transformation*. That same year, L.A. Pipes published the first explicit application of the method to electrical engineering problems in *Philosophical Magazine*, in a paper titled "Laplacian Transform Circuit Analysis." These works reduced Heaviside's tricks to routine methods. The technique quickly spread, and in the United States, *Transients in Linear Systems: studied by the Laplace Transformation*—the still classic text, known to generations of EEs as "Gardner and Barnes"—was published in 1942.

More recently still, the development of computer programs that simulate even highly nonlinear circuits has threatened the practical importance of the Laplace transform. Small enough to run on desktop PCs, yet powerful enough to provide the steady-state and transient behaviors of multistage electronic circuits, such software packages have made the Laplace transform more important for the theoretician than for the practical designer and analyst. Will the Laplace transform (like stress analysis in bridge struts) become one of those concepts learned in engineeering school but never used on the job?

TO PROBE FURTHER. A good guide to the early literature on the Laplace transform and Heaviside's methods is Thomas J. Higgins, "History of the Operational Calculus as Used in Electric Circuit Analysis," *Electrical Engineering*, Vol. 68, January 1949, pp. 42–45.

Also see "Strange Mathematics," Chapter 10 of *Oliver Heaviside: Sage In Solitude* by Paul J. Nahin (IEEE Press, New York, 1988) and "Euler's Version of the Laplace Transform" by Michael A.B. Deak in in *The American Mathematical Monthly*, Vol. 87, April 1980, pp. 264–269.

ABOUT THE AUTHOR. Paul J. Nahin is associate professor of electrical engineering at the University of New Hampshire in Durham. A member of the IEEE History Committee, his newest book is *Time Machines: Time Travel in Physics and Science Fiction*. ◆

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Calendar

(Continued from p. 18H)

mation Theory (IT); June 23–28; Budapest Conference Center, Budapest, Hungary; Anthony Ephremides, Department of Electrical Engineering, University of Maryland, College Park, Md. 20742; 301-405-3641.

Power Electronics Specialist Conference–PESC '91 (PEL); June 24–28; Massachusetts Institute of Technology (MIT), Cambridge; Martin Schlecht, MIT, Room 39-553, Cambridge, Mass. 02139; 617-253-3407.

Transducers '91: International Solid-State Sensors and Actuators Conference (ED); June 24–28; Hyatt Regency Hotel, San Francisco; Richard S. Muller, 497 Cory Hall, Berkeley Sensor and Actuators Center, University of California at Berkeley, Berkeley, Calif. 94720; 415-642-0614.

JULY

28th IEEE Nuclear and Space Radiation Effects Conference (IEEE Nuclear and Plasma Sciences Society); July 15–19; Town and Country Hotel, San Diego, Calif.; James R. Schwank, Sandia National Laboratories, Division 2144, Box 5800, Albuquerque, N.M. 87185; 505-846-8485.

AUGUST

26th Intersociety Energy Conversion Engineering Conference–IECEC '91 (ED); Aug. 3–9; Boston Marriott Hotel, Boston; Patrick Bailey, Lockheed Missiles & Space Co., 1111 Lockheed Way (59-32-535), Sunnyvale, Calif. 94088; 408-756-4268.

Cornell Conference on Advanced Concepts in High Speed Semiconductor Devices and Circuits (ED); Aug. 5–7; Cornell University, Ithaca, N.Y.; R.J. Trew, North Carolina State University, Electrical and Computer Engineering Department, Box 7911, Raleigh, N.C. 27695; 919-737-2336.

International Symposium on Electromagnetic Compatibility–EMC '91 (EMC et al.); Aug. 13–15; Hyatt Cherry Hill, Cherry Hill, N.J.; Henry W. Ott, 45 Baker Rd., Livingston, N.J. 07039; 201-386-6660.

SEPTEMBER

Bipolar Circuits and Technology Meeting (ED); Sept. 9–10; Minneapolis Marriott Hotel, Minneapolis, Minn.; John Shier, 2401 E. 86th St., Bloomington, Minn. 55425; 612-851-5228.

Seventh Multidimensional Signal Processing Workshop (SP); Sept. 23–25; Whiteface Inn, Lake Placid, N.Y.; John Woods, Computer and Systems Engineering, Rensselaer Polytechnic Institute, Troy, N.Y. 12181; 518-276-6079.

18th International Conference on Computers in Cardiology (COMP et al.); Sept. 23–26; Venice, Italy; Corso Stati Uniti 4, 35020 Padova, Italy; (39+49) 829 5702.

International Symposium on Gallium Arsenide and Related Compounds (ED); Sept. 23–26; Seattle, Wash.; L. Ralph Dawson, Sandia National Laboratories, Division 1144, Albuquerque, N.M. 87185; 505-845-8920.

Fourth Annual International Application Specific Integrated Circuits Conference and Exhibit (IEEE Rochester et al.); Sept. 23–27; Rochester Riverside Convention Center, Rochester, N.Y.; Kenneth W. Hsu, Department of Computer Engineering, Rochester Institute of Technology, Rochester, N.Y. 14623; 716-475-2655; fax, 716-475-6879.


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Recent books

(Continued from p. 13)

Image Analysis Applications. Ed. *Kasturi, Rangachar, and Trivedi, Mohan M.*, Marcel Dekker, New York, 1990, 464 pp., $115.

A Computational Model of Metaphor Interpretation (Perspectives in Artificial Intelligence Series, Vol. 8). *Martin, James H.*, Academic Press, San Diego, Calif., 1990, 229 pp., $34.95.

A Digital Design Methodology for Optical Computing. *Murdocca, Miles*, MIT Press, Cambridge, Mass., 1990, 162 pp., $30.

Schaum's Solved Problems Series: 2000 Solved Problems in Electronics. *Cathey, Jimmie J.*, McGraw-Hill, Hightstown, N.J., 1990, 532 pp., $19.95.

Music, Sound, and Technology. *Eargle, John M.*, Van Nostrand Reinhold, New York, 1990, 290 pp., $39.95.

The Elements of Nonlinear Optics. *Butcher, P. N., and Cotter, D.*, Cambridge University Press, New York, 1990, 344 pp., $49.50.

Useful Network Theorems with Applications. *Stockman, Harry E.*, Sercolab, 1990, 230 pp., $12.50.

More C Tools for Scientists and Engineers. *Baker, Louis*, McGraw-Hill, New York, 1990, 308 pp., $29.95.

Connectionist Robot Motion Planning. *Mel, Bartlett W.*, Academic Press, San Diego, Calif., 1990, 165 pp., $29.95.

Uncertainty. *Morgan, M. Granger, and Henrion, Max*, Cambridge University Press, New York, 1990, 332 pp., $44.50.

Complexity, Entropy and the Physics of Information. Ed. *Zurek, Wojciech H.*, Addison-Wesley, New York, 1990, 544 pp., $29.25.

Shared Minds. *Schrage, Michael*, Random House, New York, 1990, 227 pp., $19.95.

Microsoft Works on the Apple Macintosh. *Rubin, Charles*, Microsoft Press, Redmond, Wash., 1986, 345 pp., $18.95.

Ethical Issues in Engineering. *Johnson, Deborah G.*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 392 pp., $27.33.

The Personal Computer Book. *McWilliams, Peter*, Prelude Press, Los Angeles, Calif., 1990, 672 pp., $19.95.

Managing the Design-Manufacturing Process. *Ettlie, John E., and Stoll, Henry W.*, McGraw-Hill, New York, 1990, 285 pp., $49.95.

Analog and Digital Communication Systems. *Roden, Martin S.*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 505 pp., $56.

Semiconductors and Semimetals–Vol. 32; Strained-Layer Superlattices: Physics. *Pearsall, Thomas P.*, Academic Press, San Diego, Calif., 1990, 275 pp., $74.50.

Electrical Machines, Drives, and Power Systems. *Wildi, Theodore*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 727 pp., $47.

MS-DOS Commands. *Wolverton, Van*, Microsoft Press, Redmond, Wash., 1990, 122 pp., $7.95.

Hydropower Engineering Handbook. *Gulliver, John S., and Arndt, Roger E.A.*, McGraw-Hill, New York, 1990, 672 pp., $65.

X Window System Toolkit. *Asente, Paul J., and Swick, Ralph R.*, Digital Press, Bedford, Mass., 1990, 1000 pp., $44.95.

Fundamentals of Piezoelectricity. *Ikeda, Takura*, Oxford University Press, New York, 1990, 263 pp., $98.

(Continued on p. 60G)

OUTSTANDING

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(Continued from p. 60D)

MS-DOS Batch Files. *Jamsa, Chris,* Microsoft Press, Redmond, Wash., 1989, 166 pp., $6.95.

Modern Signals and Systems. *Kwakernaak, Huibert, and Sivan, Raphael,* Prentice-Hall, Englewood Cliffs, N.J., 1991, 791 pp., $56.

PC Tools Deluxe. *Townsend, Carl,* Microsoft Press, Redmond, Wash., 1990, 156 pp., $7.95.

X Window System. *Scheifler, Robert W., and Gettys, James,* Digital Press, Bedford, Mass., 1990, 851 pp., $49.95.

The IMS/VS Expert's Guide. *Lyon, Lockwood,* Van Nostrand Reinhold, New York, 1990, 254 pp., $32.95.

The Norton Utilities. *Wolverton, Van,* Microsoft Press, Redmond, Wash., 1990, 122 pp., $7.95.

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The Ocean in Human Affairs. *Singer, S. Fred,* Paragon House, New York, 1990, 374 pp., $34.95.

PC Tools Deluxe. *Nelson, Stephen L.,* Microsoft Press, Redmond, Wash., 1990, 395 pp., $22.95.

X and Motif Quick Reference Guide. *Rost, Randi J.,* Digital Press, Bedford, Mass., 1990, 240 pp., $24.95.

Assurance Technologies. *Raheja, Dev G.,* McGraw-Hill, New York, 1990, 341 pp., $49.50.

Handbook of Polymer Coatings for Electronics. *Licari, James J., and Hughes, Laura A.,* Noyes Publications, Park Ridge, N.J., 1990, 392 pp., $75.

Advances in Electronics and Electron Physics, Supp. #21: Coulomb Interactions in Particle Beams. *Jansen, G.H.,* Academic Press, New York, 1990, 546 pp., $89.

Systems & Control Encyclopedia: Supplementary Volume 1. Ed. *Singh, Madan G.,* Pergamon Press, Oxford, England, 1990, 658 pp., $295.

Entropy and Information Theory. *Gray, Robert M.,* Springer-Verlag, New York, 1990, 332 pp., $53.50.

Practical Volume Holography. *Syms, R.R.A.,* Oxford University Press, New York, 1990, 399 pp., $98.

Computer Ethics: Cautionary Tales and Ethical Dilemmas in Computing. *Forrester, Tom, and Morrison, Perry,* MIT Press, Cambridge, Mass., 1990, 193 pp., $19.95.

Dictionary of Computing. Ed. *Glaser, Edward L., and Pyle, I.C.,* Oxford University Press, New York, 1990, 510 pp., $39.95.

The Automated Factory Handbook. *Cleland, David I., and Bidanda, Bopaya,* TAB Books, Blue Ridge Summit, Pa., 1990, 812 pp., $69.95.

Automatic Control Systems. *Kuo, Benjamin C.,* Prentice-Hall, New York, 1991, 760 pp., $56.

Expert Systems Applications for the Electric Power Industry, Volumes I and II. *Naser, Joseph A.,* Hemisphere Publishing, Bristol, Pa., 1990, 1462 pp., $185.

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Kinematic Geometry of Mechanisms. *Hunt, K.H.,* Oxford University Press, New York, 1990, 399 pp., $51.

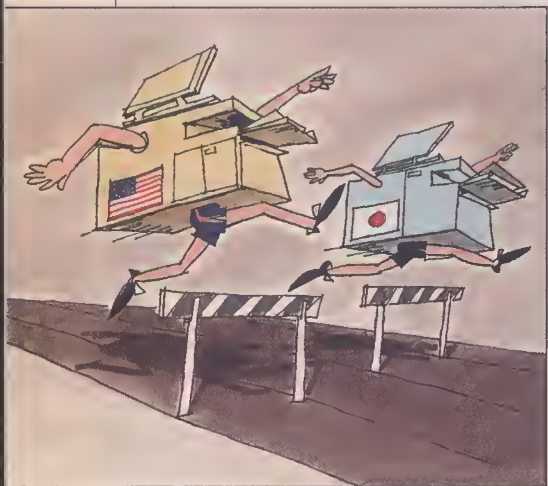
Managing technology

Getting copiers to market: Japan vs. the United States

The latest evidence that competitiveness of U.S. companies is hurt by the costs incurred in coordinating and monitoring technological innovation has emerged from a study of the plain paper copier industry.

Conducted by Philip H. Birnbaum-More, a professor of management at the University of Southern California Graduate School of Business Administration, and Joseph T. Gilbert, a doctoral student there, the study highlights results of their investigations of the performance of 23 firms in the United States, Japan, and Europe between 1974 and 1984.

The two researchers found that although



Tony Leonardi

outsourcing varied by market segment, seven of the nine Japanese firms manufactured their copiers internally, while two relied on outsourcing through original-equipment manufacturer arrangements. It was just the reverse for the U.S. firms: seven outsourced their manufacturing, while two manufactured copiers internally.

In both situations, however, the Japanese were faster than their U.S. counterparts in the time it took to bring a product to market, in successive product introductions by the same firm (cycle time), and in introducing products to compete with new products of other firms (response time).

The U.S. firms that manufactured internally were faster than those that outsourced, but they were still slower than all the Japanese firms. (The Japanese firms that outsourced were faster than those that manufactured internally.)

Both the Japanese and the U.S. firms were faster than the European firms, all of which outsourced.

Birnbaum-More told *IEEE Spectrum* that he believes the reason the Japanese have a speed advantage over the U.S. firms (he is not sure about the Europeans) lies in the monitoring and coordinating of supplier relationships.

"Japanese firms know their suppliers very well and don't spend a lot of time signing documents and getting all of the legal contracting straight. Basically, it's done on the basis of trust and a handshake, and the recourse if a supplier fails to live up to the agreement is simply that he will never be used again."

A paper on this work, which is part of a broader investigation of competitive product timing in the copier, semiconductor microprocessor and dynamic RAM, and facsimile industries, is being published. For a copy, write Birnbaum-More at the Department of Management and Organization, Graduate School of Business Administration, University of Southern California, Los Angeles, Calif. 90089-1421.

Developing young engineers

R&D researchers generally assume that a challenging job prompts a young engineer to perform that job better. But some managers argue that job performance is a cause rather than an effect, and that certain people are naturally high performers, who are motivated to select, and more likely to be selected for, more challenging assignments.

To sort out what may be actually happening, Denis M.S. Lee studied the causal relations among job challenge, workload, and job performance of 210 young engineers ("Job Challenge, Work Effort, and Job Performance of Young Engineers: A Causal Analysis," to appear soon in *IEEE Transactions on Engineering Management*).

Lee, who is professor of computer information systems at Suffolk University, Boston, studied the engineers at two times: first, during their industrial assignments in a college cooperative program, and then three years later, after they had completed at least two years' full-time professional work.

Lee found that job challenge and work effort have a direct effect on current job performance, and that these effects become stronger over time.

In other words, young engineers do get higher performance ratings on jobs that are more challenging. In addition, however (and this has not been demonstrated before, Lee told us), challenging jobs lead engineers over time to seek other jobs that are even more challenging.

Lee explained that a subtle learning effect appears to be key in this causal relationship between early work experience and performance. "It's what engineers learn in the organization that determines their long-term performance, not technical education nor anything else," he said.

This has implications for the treatment of newly hired engineers. Stressing that "we need to change fundamentally the way young engineers develop," Lee asserted that "today's environment is disastrous for them." Pointing to previous studies showing that high-performing young engineers are more effective communicators and information-gatherers than their lower-performing colleagues, he told us that management should do more to integrate new engineers into the organization and provide them with challenging assignments.

Diversity in R&D groups

Women, minorities, and the foreign-born are joining the technical workforce in increasing numbers. This heterogeneity has its advantages—notably, the opportunity to fill jobs with the best people. But there are problems as well, brought about by differing communications and behavior patterns, expectations, and attitudes toward work—and by supervisors' reactions to these differences.

Diversity in the R&D groups at five major companies was studied recently by three management professors from Rutgers University, Newark, N.J.—George G. Gordon, Nancy DiTomaso, and George F. Farris ("Managing Diversity in R&D Groups," *Research Technology Management*, January–February 1991, pp. 18–23).

Among other recommendations, they urge that all employees, especially those from cultural groups new to the organization, be given a better orientation about the company's cultural norms. Such orientation should cover: how to behave in meetings; how to work with superiors, peers, and support staff; which activities are likely to be recognized and rewarded; how to negotiate good assignments; when it is permissible to break the rules; and promotion policies.

Ideally, individual managers will provide newcomers with this orientation, but it may be necessary to organize formal programs and even encourage special support groups. Also helpful would be to mix new and "traditional" engineers in the same office.

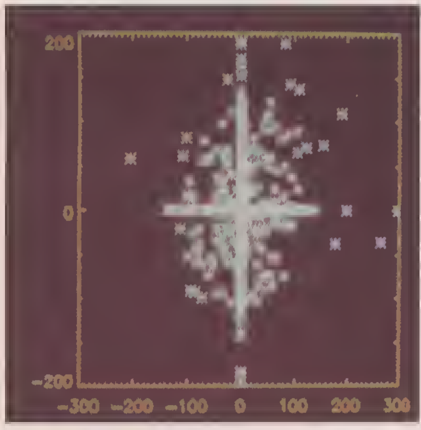
COORDINATOR: Michael F. Wolff
CONSULTANTS: Robert F. Cotellessa, Clarkson University; John Griffin, McKinsey & Co.

EEs' tools & toys

Seeing more with visual data analysis

Engineers and scientists who must analyze large amounts of data should consider a new method of analysis—visual data analysis (VDA). To produce novel ways of viewing data, VDA combines traditional data analysis, graphics, and file management with visualization, which includes animation or shading the display so as to aid the viewer in spotting trends or patterns.

One VDA product is PV Wave. It can help you figure out what format your data is in, read it, analyze it with one of several mathematical functions, and graph it on your display. It offers several types of charts: surface, two-, three-, or *n*-dimensional plots and vector, raster, or volumetric representations. Hard copy output is also available.



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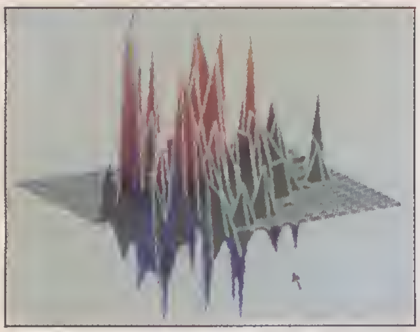

Visualization software allows data to be plotted in different ways. The scatter plot is one view of data produced by vibration sensors on an automobile (top). The same data can be represented by a surface plot (below).

With the newest version of PV Wave, dubbed Point and Click, a mouse is needed to select the desired function. Data can easily and quickly be imported and analyzed. Several different graphs and/or tables of numbers may be viewed simultaneously. With the aid of the mouse, portions of any graph can be blown up to show detail. Values can also be represented by hues of color.

For greater flexibility, the older Command version provides a high-level language and can be used in conjunction with traditional languages such as C. It does not allow the use of a mouse. Like the other version, it redraws the screen quickly without the use of a video accelerator.

PV Wave Point and Click carries a list price of US $4500. The Command version has been available for several years and has the same price. Both are available on several platforms, such as the Sun Sparc workstation, and come with a 60-day money-back guarantee. *Contact: Terri Douglas, Precision Visuals Inc., 6260 Lookout Rd., Boulder, Colo. 80301; 303-530-9000, ext. 402,* **or circle No. 101.**

TOYS

The once and future sky

If you've always wanted to know what the sky looked like in, say, 4000 B.C. or how it will look in about 10 000 A.D., or any time in between, you might consider EZ Cosmos. The computer simulation displays more than 10 000 celestial objects both from our solar system and far out into deep space. The sky may be viewed from any point on Earth, or you may zoom to a close-up of any object. You can select any object with a mouse, arrow keys, or by typing in its name; the program can then display the object's vital statistics in tabular form.

In lieu of a telescope, EZ Cosmos Version 3.0 requires an IBM or compatible computer, 512K bytes of RAM, and either a VGA, EGA, CGA, or Hercules monitor. It sells for $69.95 plus $5 shipping. Order it directly from the developer, and you'll also receive a 30-day, money-back guarantee (less shipping), and a free subscription to *Astronomy Magazine. Contact: Future Trends Software, Box 1418, DeSoto, Texas 75115; 800-869-3279,* **or circle No. 106.**

CATALOG

Products listed on a disk

Want a quick way to search through a manufacturer's catalog? Try Burr-Brown's electronics catalog, an IBM PC–compatible floppy disk listing the company's analog, analog-to-digital, digital-to-analog, DC-to-DC converters, instrumentation amplifiers, multiplexers, operational amplifiers, and other components. It is a simple matter to display, for example, a list of all analog devices with a maximum of 0.1 percent feedthrough and 0.5 percent total error (13 such devices are listed). You can then display or print detailed specifications.

Burr-Brown updates the list twice a year by mailing out a new disk. The catalog is free from the manufacturer, which needs to know your name, title, company, and address. *Contact: Burr-Brown Corp., Literature Distribution Center, Box 11400, Tucson, Ariz. 85734,* **or circle No. 102.**

Software product directories

The army of PC software products parades through a series of new directories that could be of interest to the engineer. PC Techware Special Editions focus on software for the technical user. The engineering/programming edition includes software for 51 categories, including artificial intelligence, computer-aided software engineering, communications, electronics, graphics, and programming tools. There is also a manufacturing edition. Each edition sells for $75.

Also available are product reports that list key features, price, system requirements, and a company contact for each product covered. These reports cover 85 categories and are priced between $10 and $45, depending on the number of products in the category. *Contact: Information Age Publishing, 40 Beech Hill Rd., Exeter, N.H. 03833; 603-778-1186,* **or circle No. 107**

SOFTWARE

Electrical distribution analysis

Electric utilities needing software for analyzing power distribution have many products to choose from. However, if they want the convenience of Microsoft's Windows 3.0 graphical interface, they might look into Distribution Primary Analysis/Graphics (Dpa/g) version 3.0.

According to the developer, Dpa/g offers full-featured analysis for a utility's distribution system from step-down stations to customers. It displays a graphical representation of the distribution system, and the user can then select or modify any component with the aid of a mouse. Calculations performed by the package include balanced and unbalanced voltage analysis, power losses, and fault currents, as well as optimization of capacitor placement. The user may also access the relational data base with the Structured Query Language (SQL).

Dpa/g is available for $12 500. *Contact: Scott & Scott, Fourth & Blanchard Build-*

EEs' tools & toys

ing, Suite 303, 2101 Fourth Ave., Seattle, Wash. 98121-2375; 800-325-1494, **or circle No. 103.**

Nuclear analysis on a PC

Nuclear multichannel analyzers for IBM PC compatibles have been around for about seven years. Now, one vendor has revised its product to run under Microsoft's Windows 3.0. The Maestro software package can display several spectra simultaneously, identify spectra peaks, perform nuclide identification, and calculate online activity.

Maestro makes use of Windows in several ways. The graphical interface provides the user with an easy means of examining data and requesting analysis. Multiple copies may be displayed simultaneously. And in 80386-based systems different tasks can be executed simultaneously (multitasking).

Maestro works with the Spectrum Master line of data acquisition hardware built by the same vendor. It is available now for $850. *Contact: EG&E Ortec, 100 Midland Rd., Oak Ridge, Tenn. 37831-0895; 800-251-9750,* **or circle No. 104.**

The sound of data

If seeing it isn't good enough, you might consider listening to your data. Mathematica 2.0 converts your data into sound on computers such as the Macintosh or NeXT that have built-in audio capability. If your workstation has a lab notebook environment you will even be able to paste sound into documents. The program allows any mathematical function to be converted into audio because the developer feels that sound is a very useful method of interpreting and analyzing data. Douglas Stein, a software engineer at the company, went so far as to say "sound is graphics and graphics is sound."

Precision Visuals Inc.

Work in knot theory, a branch of pure mathematics, can be aided by Mathematica's parametric plotting facility. Shown is a (3,4)-torus knot. Similar figures have been applied to molecular biology and theoretical physics.

But even if your computer does not support sound, you can benefit from this visual data analysis tool. The high-level command language allows numeric, symbolic, and graphical computation. Platform-specific front ends allow it to be used interactively. There are 843 mathematical functions to choose from.

Mathematica 2.0 is to become available before the second quarter of 1991 on many platforms, including 386-based machines and Macintosh and Unix workstations. Until it is ready, customers may buy Version 1.2 at a 25 percent discount and receive a free upgrade to Version 2.0 later. Prices start at $595 for the standard Macintosh version. *Contact: Wolfram Research Inc., 100 Trade Center Dr., Champaign, Ill. 61820; 217-398-0700,* **or circle No. 105.**

REFERENCES

The world at your fingertips

New atlas programs from The Software Toolworks bring valuable information to those involved in international business or just interested in the world around them. The same source also supplies a reference library on ROM.

World Atlas combines an atlas, almanac, and fact book for research in seven areas: geography, people, government, travel, economy, defense, and communications. Countries are presented in more than 240 EGA/VGA color maps, which can be exported in a number of standard formats to desktop publishing, paint, or word-processing programs. A U.S. Atlas, containing detailed information on the United States, is also available. Data can be recalled by state or city and includes information on topics such as population, tourism, latitude and longitude, and highways. The software runs on IBM PC, XT, AT, and PS/2 computers and compatibles and is also available for Macintosh computers. Compact-disc ROM (CD-ROM) versions are also available.

The World Atlas and U.S. Atlas are $59.95 each. The Atlas Pack, a combination of both atlases, is available for $109.95.

The Software Toolworks' reference library packs volumes of frequently used sources into a single CD-ROM. Included are *The New York Public Library Desk Reference, Webster's New World Dictionary* (third edition), *Webster's New World Thesaurus* and *New World Guide to Concise Writing, Dictionary of 20th Century History,* J.K. Lasser's *Legal and Corporation Forms for the Smaller Business,* and the *National Directory of Addresses and Telephone Numbers.*

The reference is available for IBM and compatible computers for $149. *Contact: The Software Toolworks, 60 Leveroni Court, Novato, Calif. 94949; 800-231-3088; fax, 415-883-3303, or* **circle 108** *for the atlases,* **109** *for the CD-ROM library.*

COORDINATOR: Dennis DiMaria

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The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

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Academic
Positions Open

Auburn University—Earle C. Williams Eminent Scholar Chair in Electrical Engineering. Nominations and applications are invited for the Earle C. Williams Eminent Scholar Chair in Electrical Engineering. Candidates for this chair should have achieved national and international prominence in digital systems and/or microelectronics. Applicants or nominees must have an earned doctorate, senior academic experience, and a documented record of distinction in university teaching and research. The successful candidate will be expected to provide intellectual leadership in his/her area of expertise for the Department of Electrical Engineering as well as enrich the scholarly environment at Auburn University. Auburn University is located in the city of Auburn in east-cental Alabama. This land-grant univeristy enrolls more than 21,000 students, the largest on-campus enrollment in the state. The Department of Electrical Engineering, one of eight departments within the College of Engineering, offers Bachelor, Master, Master of Science and Ph.D. degrees in Electrical Engineering. The department has a current enrollment of 939 undergraduate students and 100 graduate students. The 28 full-time faculty have an annual research expenditure of approximately $2 million. The Search Committee will begin its review of applications immediately. Interested candidates should submit: (1) a detailed resume, (2) a letter indicating an interest in the chair, the candidates's academic philosophy, and a brief statement of accomplishments in teaching and research, and (3) names and addresses of five references. Nominations should be submitted with the complete name, mailing address and telephone number of the individual nominated. Applications and nominations should be sent to Professor J. David Irwin, Department of Electrical Engineering, Auburn University, AL 36849-5201. Auburn University is an affirmative action/ equal opportunity employer. Applications from minority and female candidates are encouraged.

University of Illinois at Urbana-Champaign. The Departments of Electrical and Computer Engineering invites applications for several tenure track and tenured faculty positions. Applicants must have an earned Ph.D., outstanding academic credentials, and an ability to teach effectively at both the graduate and undergraduate levels. Selected candidates will be expected to initiate and carry out independent research and to perform academic duties associates with our B.S., M.S., and PhD. programs. The department has one of the largest programs in the United States granting approximately 400 B.S., 100 M.S. degrees and 65 Ph.D. degrees. Research is conducted in acoustics, bioengineering, communications, computer engineering, computer vision & robotics, control, electromagnetics, integrated circuits, laser and electro-optics, microelectronics, power systems and power electronics, signal processing, and remote sensing. Particular need exists for faculty in communication systems. However, all candidates judged to have outstanding qualifications for a position in any of the above areas will be interviewed. The University of Illinois is an equal opportunity/affirmative action employer. Send resume, with references and a list of publications, to: Faculty Search Committee, Department of Electrical and Computer Engineering, 1406 West Green Street, University of Illinois, Urbana, IL 61801.

University of Illinois at Chicago—Instructorships and Tenure-Track faculty positions in electrical engineering and computer science at both the junior and senior level are available. Rank and salary commensurate with qualifications. An earned Doctorate in EE or CS must be completed by date of appointment, but not for the instructorships. Demonstrated teaching and research abilities are highly desirable. For full consideration, please send resume, list of publications, and the names of at least three references by April 30, 1991, to Dr. Wai-Kai Chen, Head, Department of Electrical Engineering and Computer Science (M/C 154), University of Illinois at Chicago, P.O. Box 4348, Chicago, IL 60680. The University of Illinois is an Affirmative Action/Equal Opportunity Employer.

Texas **A&M University**. The Electrical Engineering Department has several openings for tenure track faculty at all ranks. Applicants must have a Ph.D. degree. For senior positions, the individuals should have a proven record of scholarly contributions, and for junior positions, demonstrated potential for quality research and teaching is necessary. The salary is competitive and commensurate with qualifications and experience. The Department has 1300 undergraduate students, 350 graduate students and a faculty of 56. Currently the active areas of graduate programs include digital and analog microelectornics , electronic and magnetic materials and devices, electromagnetics, micorowave engineering, computer engineering, electrooptics, telecommunications, controls, signal processing, electric power systems, and power electronics. Qualified individuals having expertise in any of these research areas are urged to apply. The Department has a particular interest in hiring outstanding faculty in the areas of computer engineering, microelectronics, electronic materials, electromagnetics, microwave engineering, power systems automation, solid state electronics and signal processing. Applicants should send a complete resume, including names and addresses of three references to Dr. J.W. Howze, Department Head, Electrical Engineering Department, Texas A&M University, College Station, TX 77843. Texas A&M University is an equal opportunity/affirmative action employer, and actively seeks the candidacy of women and minorities.

Illinois Institute of Technology, Department of Electrical and Computer Engineering invites applications for tenure track and tenured faculty positions in the areas of computer, communication, electromagnetics, and power. Please send resume to Chair of Faculty Search Committee, Department of Electrical and Computer Engineering, Illinois Institute of Technology, Chicago, Illinois 60616. IIT is an equal opportunity/affirmative action employer.

Electrical Engineering: Tenure track position available July 1, 1991 at the assistant professor level (higher rank considered based on experience). We are looking for someone with a background in power systems and/ or electromechanical energy conversion. A strong commitment to undergraduate teaching is essential as is a desire to become involved in our broad-based lab oriented curriculum. Ph.D. preferred but will consider M.S. with significant relevant experience. U.S. citizenship or permanent residency strongly preferred. Norwich University is located in an area of central Vermont that offers small-town or rural living with good schools and outstanding recreational opportunities. Send resume and references to: Prof. William Till, Chairman, Dept. of Electrical Engineering, Norwich University, Northfield, VT 05663. Position open until filled. EOE, women encouraged to apply.

Faculty Positions in the Electrical Engineering Department at The University of North Carolina at Charlotte, Charlotte, NC 28223. The Electrical Engineering Department at the University of North Carolina at Charlotte invites applications for two tenure-track positions at the Assistant, Associate, or Full Professor level. Areas of interest include signal and image processing/ communications (including optical signal processing and telecommunications), and microelectronics (including optoelectronics, process technology, system integration, nonometric devices, and analog/digital VLSI design). Positions begin Fall of 1991. The University of North Carolina at Charlotte is one of the largest institutions of the UNC system. It has over 14,000 students, including 2,125 graduate students in the six colleges. The department is one of five in the College of Engineering and currently enrolls 350 students, of which 50 are graduate students and Postdoctoral Research Associates. Computer facilities include micros, minis, workstations and free access to Cray YMP supercomputer. The laboratory facilities include a class 100 clean room with complete integrated circuit and microstructure fabrication capabilities, laboratories for measuring the electrical properties of the insulator-semiconductor surface, computerized IC test facilities, laser electro-optic laboratory, dry processing laboratory for VLSI fabrication, and MBE laboratory for quantum well superlattice and optoelectronic materials. As a participating institution of MCNC (Microelectronics Center of North Carolina), the faculty have access to the MCNC facilities with capabilities of submicron IC design, fabrication, test, and semiconductor materials analysis. Charlotte is the largest city in the Carolinas and offers good schools and attractive housing. The 100,000 sq. ft. engineering building and a 75,000 sq. ft. applied research building are located adjacent to the 2,800 acre University Research Park. Various forms of career development support are available. Applicants should have a Ph.D. degree or equivalent and have commitment to teaching and pursuing research. Industrial and research experience is desirable. Rank and salary commensurate with experience. Applications will be accepted until March 1, 1991. Initial screening begins February 1, 1991. Applications, including a resume and four references, should be sent to: Rafic Makki, Chairman, Search Committee, Electrical Engineering Department, UNC-Charlotte, Charlotte, NC 28223. UNC-Charlotte is an equal opportunity affirmative action employer, and complies fully with the Immigration Reform and Control Act of 1986.

Electronic Engineering Technology. Mankato State University invites applications for tenure track position in ABET accredited four-year program. An earned Doctorate degree is preferred but serious consideration is given to an MS degree with recent industrial experience in elec-

trical engineering. Rank and salary are negotiable. Salaries are competitive. Preference is given to individuals with interests in power electronics and electromechanics. The Department offers a stimulating professional environment, excellent computer and shop facilities as well as newly equipped microprocessor, communications, control, microelectronics and electromechanics laboratories. Mankato State University has an enrollment of 16,000 students and is located 70 miles southwest of the Minneapolis/St. Paul metropolitan area. Send resume indicating teaching interests, experience and names of three references with phone numbers to: Dr. Carl Gruber, Chairman, Department of Electrical Engineering and Electronic Engineering Technology, MSU Box 215, Mankato State University, Mankato, MN 56002-8400; (507) 389-6536. Deadline March 31 or until filled.

The **Johns Hopkins University,** Department of Electrical and Computer Engineering, invites applicants for tenure-track faculty positions at the Assistant or Associate Professor level, in the solid state/quantum electronics area and in computer engineering. Candidates for Associate Professor appointments are expected to have significant research records and a demonstrated ability to develop funded research programs. Candidates for Assistant Professor appointments are expected to show strong research potential. All candidates should have a doctorate (preferably in electrical engineering) and a strong commitment to teaching and research. Applications should be sent to Professor C.R. Westgate, Chair, Department of Electrical and Computer Engineering, The Johns Hopkins University, Baltimore, MD 21218. The Johns Hopkins University is an equal opportunity/affirmative action employer.

The Bradley Department of Electrical Engineering of Virginia Polytechnic Institute and State University invites applications for several tenure track faculty positions. Greatest needs are in the areas of electronic materials (a joint position with Materials Engineering Department) and communications with emphasis on high frequency electronics. Consideration will be given to applicants in all areas at the Assistant and Associate Professor level. Applicants must have an earned doctorate, be interested in undergraduate and graduate teaching, and be willing to secure research sponsorship. Virginia Tech is Virginia's land grant university offering degrees through the Ph.D. Send complete resume with references and employment/citizenship status to: Prof. W.L. Stutzman, Chairman, Personnel Committee, Bradley Department of Electrical Engineering, Virginia Tech, Blacksburg, VA 24061-0111. Applications will be accepted until April 15, 1991, or until suitable candidates are selected. Virginia Tech is an Equal Opportunity/Affirmative Action Employer.

The Bradley Department of Electrical Engineering and the Department of Materials Engineering of Virginia Polytechnic Institute and State University invites applications for a joint appointment in the Electrical Engineering and Materials Engineering Departments. The Associate Professor position will be half-time in each department with teaching and research responsibilities in both. The Bradley Department of Electrical Engineering has 55 faculty, 1100 undergraduate students, and 300 graduate students. Annual research expenditures exceed $4 million. The EE Department has many research and teaching laboratories including the Electronic Materials and the Hybrid Microelectronics Laboratories. The Department of Materials and Engineering consists of 13 faculty and approximately 80 undergraduate and over 40 graduate students. The curriculum includes topics in the areas of ceramic, metallic, polymeric, electronic and composite materials. Current research funding is approximately $1.4 million annually. Many opportunities exist for interdisciplinary research with centers on campus performing related research. Applicants must have an earned doctorate, be interested in undergraduate and graduate teaching,,and be willing to secure research sponsorship. Virginia Tech is Virginia's land grant university offering degrees through the Ph.D. Applications from members of minority groups and women are encouraged. Send complete resume with references and employment/citizenship status to: Professor W.L. Stutzman, Chairman, Personnel Committee, Bradley Department of Electrical Engineering, Virginia Tech, Blacksburg, VA 24061. Applications will be accepted until May 15, 1991, or until suitable candidates are selected. Virginia Tech is an Equal Opportunity/Affirmative Action Employer.

Telecommunications—SMU. The Electrical Engineering Department in the School of Engineering and Applied Science at Southern Methodist University has an opening for a senior level tenure-track position in the area of telecommunications. Rank and salary are commensurate with qualifications. Candidates for this position must be able to provide leadership for the development of a nationally recognized program of research, instruction, and industrial collaboration in modern digital and analog switched telecommunication systems. Of particular but not exclusive interest are the areas of software technology applied to integrated broadband communications and computing environments; network architecture and protocol design for broadband high speed communications; interconnection of local area networks; and performance analysis and modeling of multi-media communications. Candidates must have an outstanding research record, a dedication to teaching, and a commitment to promote cooperation with industry. Dallas' preeminent position in the telecommunications field provides many opportunities for collaboration. Interested individuals should send resumes and the names of three references to: Professor Jerome K. Butler, Chair, Electrical Engineering Department, SMU, Dallas, TX 75275-0335. Tel: (214) 692-3113. Applications will be accepted until April 15. Southern Methodist University is an affirmative action/equal opportunity, Title IX employer and specifically invites and encourages applications from women and minorities.

Department Head, Engineering Technology. Applicants for this 12-month position must have demonstrated teaching excellence, leadership capability and administrative experience. Instructional assignment is tenure-track. Master's in Engineering or Engineering Technology, P.E. registration, and relevant U.S. industrial experience required. Salary and rank commensurate with experience and qualifications. Position available Sep. 1, 1991. The search will continue until position filled, but first consideration will be given to completed applications received by April 1, 1991. For information, call (805) 756-1138. Submit applications to: Dean's Office, School of Engineering, Cal Poly, San Luis Obispo, CA 93407. All qualified persons, especially women and minorities are encouraged to apply. AA/EOE.

UNIX System Manager and Trainee Systems Administrator. The Institute of Systems Science is a dynamic world class institute for information and systems technology thriving on research culture and entrepreneurship; and delivering new ideas and products through research, development and education in strategic partnership with organizations. ISS has vacancies for: 1. System Manager—Your primary task is to conduct system management activities for UNIX workstations, training and supervision of system support staff reporting to you. Duties include network configuration, installation of security procedures and regular backups, procurement and vendor liaison, installation of hardware and software, technical support to research staff, long term planning and design strategies for system facilities and resources. ISS has a multi vendor computing environment. You will most likely have knowledge in the following key technologies: ethernet, TCP/IP, NFS, X-Windows, IBM SNA & 3270 Protocol, 3Com, UNIX, MS-DOS, Apple Macintosh. You will be primarily responsible for all shared workstation services. This will include network connectivity support for project specific workstations such as Silicon Graphics IRIS and IBM RS 6000 workstations. In addition to internal connectivity the candidate will have to liaise with the university on services available over the Campus LAN, specifically access to the international Internet network and mainframe and X. 400 mail gateway services. You should have a bachelor's degree from a reputable university specializing in Computer Science or Electrical Engineering and should have at least 4 years experience in systems administration and in the management of UNIX machines, good interpersonal skills, vendor development experience and experience in managing people reporting to you. 2. Trainee System Adminstrator—This position is for applicants from Asian countries who are keen to return to the region. You will assist senior system administration staff in day to day system and software installation and maintenance: and also in system programming. You will perform backups, shutdowns and monitor disk space utilization. You should possess a degree in Computer Science or Electrical Engineering from a recognized University. You should also be proficient in C and the UNIX operating system. We offera stimulating work environment in one of the most advanced computing facilities in the region. —a competitive salary and attractive fringe benefits. If you are ready to take up this opportunity, please send your resume to the Director of Personnel, National University of Singapore, 10 Kent Ridge Crescent, Singapore 0511 or fax ISS Recruitment Manager (UNIX Systems) at (65)-775-0938 or Bitnet ISSAPPLY@NUSVM.

Wright State University, Department of Computer Science and Engineering invites applicants for tenure-track and visiting faculty positions at all ranks. The successful candidate must have a Ph.D. in computer science, computer engineering, or equivalent background and have demonstrated forward looking and creative research. Further desired attributes include: capability to direct Ph.D. candidates in computer science or computer engineering and the ability to acquire funds and/or direct research projects. Preferred technical areas are distributed systems, networking, and database, but other areas will be considered. Rank and competitive salaries are determined by qualifications and experience. The University is located in a high technology environment among industrial/military research and development facilities, including Wright Patterson Air Force Base and NCR. Department strengths include a fully networked Unix environment of Sun & DEC workstations; Cray access; graduate laboratories in AI, optical computing, neural networks, and robotics; established research programs; industrial/military support; degree programs in both computer science and computer engineering; and a large graduate student population. Please submit a detailed resume including names of three references to: CSNET address—amcaulay@cs.wright.edu or Alastair D. McAulay, NCR Distinguished Professor and Chair, Department of Computer Science and Engineering, Wright State University, Dayton, Ohio 45435. Pending availability of funding, reviewing for positions will begin February 15, 1991 and continue monthly until positions are filled or until September 1, 1991. An Equal Opportunity/Affirmative Action Employer.

University of Toronto, Department of Electrical Engineering. The Department of Electrical Engineering invites applications for three tenure-stream Assistant Professor positions, one in the area of Communications and two in the area of Computer Engineering, available immediately. Subareas of specialization include, but are not limited to: telecommunication, communication networks, software systems, and computer architecture. These positions involve both research and teaching at the undergraduate and graduate levels. Applicants must have a doctoral degree, an outstanding academic record and effective teaching ability. These positions are three of several that will become available over the next three years as a result of the expansion of the Department of Electrical Engineering and the establishment of a new undergraduate program in Computer Engineering. Applicants should send a curriculum vitae, a statement concerning teaching and research interests, and a list of three references to: Professor A.S. Sedra, Chairman, Department of Electrical Engineering, University of Toronto, Toronto, Ontario, Canada M5S 1A4. In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. The University encourages both women and men to apply.

Dean of the College of Engineering, The Ohio State University. The Ohio State University invites applications and nominations for the position of Dean of the College of Engineering. The Dean will lead a distinguished 260-person faculty, serving 4,500 undergraduate and 1,400 graduate students in 16 academic units. The Dean will administer a total budget of $90,000,000, including the sixth largest engi-

neering college research budget in the United States, and will have the support of 30,500 College of Engineering alumni. The candidate should be recognized leader in administration, research and teaching. The Dean will be a key member of the university leadership and will be expected to contribute to the broad academic and cultural missions of the entire university. The position will be available July 1, 1991. The Ohio State University is an equal opportunity/affirmative action employer, and the candidate must be committed to these principles. The Search Committee will accept and review applications until the position is filled. Send applications and nominations, including curriculum vitae and the names of three references to Professor Leon Peters, Jr., Chair, Search Committee for The Dean of the College of Engineering, Department of Electrical Engineering, The Ohio State University, 2015 Neil Avenue, Columbus, OH 43210.

Clarkson University, Electrical and Computer Engineering. Applications are invited for a tenure-track faculty position as Assistant/Associate/Full Professor in the area of computer engineering. Responsibilities include undergraduate and graduate teaching and development of a research program. A doctorate is required. Review of applications will begin on March 31st and will continue until the position is filled. The department offers programs at the B.S., M.S., and Ph.D. levels. Last year 196 bachelors, 15 masters, and 7 doctorates were awarded, and research funding reach more than one million dollars. Principle research areas include distributed and parallel computation, artificial intelligence, image and signal processing, neural networks, robotics and control, communication systems solid state devices, electromagnetic scattering, power systems, and electromagnetic devices. There are research labs in artificial intelligence and neural computing, VLSI design, robotics, lasers and optics, solid state device fabrication, high voltage engineering, and dielectric breakdown. Clarkson is an independent university specializing in engineering, science and management with an enrollment of 3300 students, including 400 graduate students. Located in northern New York, Clarkson is midway between the Adirondack Mountains and the St. Lawrence River, 80 miles from Lake Placid and a two-hour drive from Ottawa and Montreal. Send applications to Professor Henry Domingos, Chairman, Department of Electrical and Computer Engineering, Clarkson University, Potsdam, New York 13699-5720. Clarkson is an Equal Opportunity/Affirmative Action Employer.

Concordia University, Department of Electrical and Computer Engineering. The Department of Electrical and Computer Engineering invites applications for a tenure-track faculty position at the assistant professor level. Candidates must have experience in analog electronic circuit design, have a familiarity with VLSI technological processes, VLSI hardware implementation of analog electronic circuits and signal processing systems. Also considered an asset is familiarity with silicon compilation of analog electronic circuits. Strong candidates in related areas will also be considered. Responsibilities include graduate and undergraduate teaching, research and supervision of graduate students. Candidates should have a Ph.D. in Electrical or Computer Engineering or Computer Science, and a strong interest in both research and teaching. The department currently has twenty-four full-time faculty members and has strong graduate and undergraduate programs. Applicants should send a resume and names and addresses of at least three references to: Dr. P.D. Ziogas, Chairperson, Department of Electrical and Computer Engineering, Concordia University, 1455 de Maisonneuve Blvd., West, Montreal, Quebec H3G 1M8. FAX: (514) 848-2802. In accordance with Canadian Immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. We also invite and encourage applications from female candidates.

Concordia University, Department of Electrical and Computer Engineering. The Department of Electrical and Computer Engineering invites applications for a full-time, tenure-track faculty position at the Assistant Professor level. Candidates should have considerable experience in the design of electric machines and ac drive systems using modern control techniques. Industrial experience in modern machines and drive systems design and development is considered very important. Responsibilities include graduate and undergraduate teaching, research and supervision of graduate students. Candidates should have a Ph.D. in Electrical Engineering, and a demonstrated interest in both research and teaching. The department currently has twenty-four full-time faculty members and has strong graduate and undergraduate programs. Applicants should send a resume and names and addresses of at least three references to: Dr. P.D. Ziogas, Chairperson, Department of Electrical and Computer Engineering, Concordia University, 1455 de Maisonneuve Blvd., West, Montreal, Quebec H3G 1M8. FAX: (514)848-2802. In accordance with Canadian Immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. We also invite and encourage applications from female candidates.

Electronics and Instrumentation: The University of Arkansas at Little Rock invites applications and nominations for the position of Chairperson for the Department of Electronics and Instrumentation. The department offers a unique interdisciplinary program leading to the M.S. and Ph.D. degrees in instrumental sciences. Current faculty represent a wide range of instrumentation disciplines, with backgrounds in chemical, electrical, civil, and biomedical engineering, as well as chemistry, computer science, and physics. Major research areas of the department are in biomedical engineering, NMR, particle technology, optics, process control, and analytical instrumentation. Candidates with backgrounds in instrumentation are encouraged to apply. Candidates must hold Ph.D. degree in a related discipline and should have an outstanding record of scholarly achievement in research and demonstrated administrative capability. The Chair is expected to provide leadership in academic and research areas, and also should plan to carry on an active research program. The appointment will be on a 12-month basis with a salary to be commensurate with qualifications and experience. Rank and tenure are negotiable. Please send application, resume and a list of three references to: Dr. Malay Mazumder, Chairman of Search Committee, Department of Electronics and Instrumentation. University of Arkansas at Little Rock, 2801 South University, Little Rock, AR 72204 by March 31, 1991. Applications received by this day are assured consideration; however, we will continue to accept applications until the position is filled. Applications will be subject to inspection under the Arkansas Freedom of Information Act. The University of Arkansas at Little Rock is an affirmative action, equal opportunity employer and actively seeks the candidacy of minorities and women.

National Chiao Tung University. The Institute of Electro-Optical Engineering invites experienced applications with Ph.D. at the Asst. and Assoc. Professor level. Specialties sought in the area of Optical System Design, Optical Materials, Infrared System. Please send resume to Prof. Shu-Hsia Chen, Director, Institute of Electro-Optical Engineering, National Chiao Tung University, 1001 Ta Hseuh Road, Hsinchu, Taiwan 30050, R.O.C. Tel: 886-35-712121-4207, 886-35-4207, FAX: 886-35-714031.

Stocker Visiting Chair in Electrical and Computer Engineering at Ohio University. Applications and nominations are being accepted for the position of Stocker Visiting Professor in Electrical and Computer Engineering (ECE). The ECE Department at Ohio University has twenty full-time and four part-time faculty, 450 undergraduate students and 80 graduate students. External research support in ECE exceeds $2.3M per year, a large portion of which comes via the Avionics Engineering Center, a unit of ECE. The ECE Department is housed in the $15M Stocker Engineering Center. The Stocker Chair position is supported through the Stocker Endowment, presently worth more than $13M. Qualifications for consideration for the Stocker Chair position include noteworthy achievements in research and teaching or industry/government. The individual selected for this position is expected to teach, participate in Departmental research, and be available to present and conduct invited seminars/lectures at various universities, including O.U. The maximum term of appointment for this position is three years; a lesser term can be negotiated. Stocker Professors are provided part-time secretarial support, a travel allowance, special office accommodations, and equipment/supplies support, if needed. In addition, modest furnished living quarters, specifically designated as Stocker Chair Apartments, are available for Stocker Professors and their spouses. Salary for the positions is negotiable. The ECE Stocker Chair position is ideal for a person who wishes to take leave from his/her present employer. Applications and nominations will be accepted until the positions is filled. Please send a resume with at least three references or your nomination to Dr. Jerrel R. Mitchell, Stocker Center, Ohio University, Athens, OH 45701-2979. Preference will be given to U.S. citizens and permanent residents. Ohio University is an equal opportunity and affirmative action employer.

Faculty Position. Cooper Industries Professor of Electrical Engineering: The Electrical and Computer Engineering Department at Ohio University is continuing its search for a senior tenure-track faculty member. The Cooper Industries Professor of Electrical Engineering will be expected to teach and develop a sponsored research program in power electronics and.or industrial controls. A demonstrated ability to interact with industrial sponsors is essential. The successful candidate is expected to take a leading role in developing a multi-disciplinary program in computer-integrated manufacturing. Candidates must have an earned Ph.D. in engineering, a demonstrated record of teaching (undergraduate and graduate) and significant experience in promoting and conducting sponsored research. Interviews will continue until the position is filled. Send resume and a list of four references to H.W. Hill, Jr., ECE Department, Ohio University, Athens, OH 45701-2979. Ohio University is an equal opportunity, affirmative action employer.

Post Doctoral positions available in Department of Electrical Engineering at Princeton University to conduct research in electronic materials, computer engineering or information science and systems. Respond to Ms. Carol Desmond, Department Manager, Dept. of EE B210 E-Quad, Princeton University, Princeton, NJ 08544. Princeton is an Equal Opportunity/Affirmative Action Employer.

The George Washington University Electrical Engineering and Computer Science Tenure-Track Faculty Positions. Tenure-track faculty positions at the assistant, associates, and full professor rank are available commencing Fall Semester 1991, in the Department of Electrical Engineering and Computer Science of the School of Engineering and Applied Science. Applicants are sought to conduct research and teach in the areas of communications, data communications/computer networks, telecommunications, computer graphics, analog electronics/VLSI, and computer engineering. Applications from other highly-qualified individuals are encouraged. Candidates should have an earned doctorate and research experience with an interest in both teaching and research. Ability to attract funded research is valued. The George Washington University main campus is located in the center of Washington, D.C. A research and graduate teaching campus, set in a major research park in suburban Virginia near Washington-Dulles Airport, will open in September 1991. Substantial equipment and student stipends are available for faculty capable of establishing government and industry-supported research projects at the new campus. Off-campus research/education programs at NASA-Goddard Space Flight Center and Melpar E-Systems provide additional opportunities for collaborative work with local industry and government laboratories. The metropolitan Washington area has the second largest concentration of research and development activity in the United States, creating a continuing demand for rigorously-trained engineers and many research opportunities. The department has 40 full-time faculty, accredited electrical engineering, computer engineering, and computer science degree programs, a large graduate and undergraduate student body, and a substantial research budget. Current projects include computer graphics, computer security, data transmission standards and compression, fast packet switching, network topologies, image processing, intelligent user interfaces, laser shields, MHD plants, magnetic devices, medical imaging, parallel processing architectures and scheduling, multipath fading and encryption, remote sensing, robot control, space-based radar, and special-purpose VLSI designs. Send curriculum vita, list

of publications and references to: Chairman, Faculty Search Committee, Department of Electrical Engineering and Computer Science, School of Engineering and Applied Science, The George Washington University, Washington, D.C. 20052. The George Washington University is an affirmative action/equal opportunity employer.

Princeton University: The Department of Electrical Engineering invites applications for a full time, tenure-track faculty position. The disciplines of particular interest are: Computer Engineering, with a specialization in computer architecture; and Digital Signal Processing, with a specialization in video and image processing. Please send a complete resume, a description of research and teaching interests and names of three references to Professor Stuart Schwartz, Chairman, Dept. of EE, Princeton University, Princeton, NJ 08544. Princeton University is an equal opportunity/affirmative action employer.

University of Hartford, Electrical Engineering Department, Faculty Position Available. The College of Engineering at the University of Hartford invites applications for two tenure-track positions within the Department of Electrical Engineering. A Chair of the department is being sought. Chair, Department of Electrical Engineering—An imaginative individual with leadership qualities is desired to chair the ten-member department. Demonstrated teaching experience at the Associate Professor level, teaching experience at the graduate level, a Ph.D., and research/industrial accomplishments are required. Faculty Position, Department of Electrical Engineering—A full-time faculty position in electrical engineering at the Assistant Professor level is open for someone with a Ph.D., a sincere interest in undergraduate and graduate engineering teaching, enthusiasm for participation in appropriate College and University committees, and an inclination toward scholarly activities involving research and/or industrial consulting. The College is planning to start a new Master of Engineering degree program with a speciality concentration in Electrical Engineering and is expanding the faculty. Backgrounds desired for these positions are electronics, electromechanical energy conversion, communications and microprocessors. Professional registration is desired. These positions are available for the Fall of 1991 semester. The College of Engineering, one of eight schools and colleges of the University of Hartford, enrolls 600 undergraduate students on a full and part-time basis. It offers ABET-accredited day and evening undergraduate programs in civil, electrical and mechanical engineering with plans to begin a master degree program in the fall of 1991. Laboratories and facilities on a spacious and modern 300 acre campus in West Hartford, Connecticut offer a full range of testing, simulation and analytical instrumentation equipment. The College of Engineering also operates an Engineering Applications Center, with the opportunity for faculty to participate in research and development with local industry. Faculty are also encouraged to teach in the University's nationally recognized interdisciplinary general education curriculum. The University and its programs in engineering, technology, the liberal arts & sciences, education, nursing, health professions, business, music, theater, and art are a vital part of Connecticut's capital city, attracting students from most states and over 60 different nations. A dedicated faculty of approximately 350 faculty are committed to excellence in professional programs and a comprehensive mission that promotes interdisciplinary learning. Candidates should submit a curriculum vita and the names and addresses of at least three references to: Professor Edward T. Friedman, Electrical Engineering Department, University of Hartford, West Hartford, CT 06117. Applications will be reviewed until the positions are filled. The University of Hartford is an equal opportunity/affirmative action employer and specifically invites and encourages applications from women and minorities.

Computer Science and Engineering. Northern Arizona University, College of Engineering and Technology is seeking applicants for a tenure track assistant professor position beginning Fall 1991. Applicants must have a Ph.D. in computer or electrical engineering with expertise in digital design, computer architecture, real time systems and microprocessor applications. Industrial experience/teaching desirable. Position will remain open until filled. Applications will be reviewed as they are received. Direct inquiries and applications to Lanny Mullens, Chair, Department of Computer Science and Engineering, College of Engineering and Technology, Northern Arizona University, Box 15600, Flagstaff, AZ 86011-1560. Northern Arizona University is a committed Equal Opportunity Affirmative Action Institution. Minorities, Veterans, Women and Handicapped are encouraged to apply.

Systems & Software Manager Position Emission Tomography Center The Dept. of Nuclear Medicine is seeking a systems & software manager for a new PET imaging Ctr. Background in computer programming & systems operation. (UNIX & C) Please send CV to: J.A. Prezio, M.D., Dept. of Nuc. Med. Univ. at Buffalo, 105 Parker Hall, Buffalo, N.Y. 14214 AA/EO Employer.

The University of Calgary, Assistant/Associate Professor in Remote Sensing. The University of Calgary Department of Surveying Engineering invites applications for the position of Assistant or Associate Professor (tenure-track) in Remote Sensing effective July 1, 1991. Qualifications: PhD in engineering or applied science; expertise in digital image processing and analysis of airborne and satellite imagery. A background in photogrammetry and automated data capture is highly desirable. Responsibilities: teach the remote sensing components including image interpretation in the graduate and undergraduate programs; develop a strong research program in digital image processing and analysis within the geomatics stream of the department. In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. The University of Calgary has an Employment Equity Program and encourages applications from all qualified candidates, including women, aboriginal people, visible minorities and people with disabilities. Applicants should send a detailed curriculum vitae, a complete list of publications and have three letters of reference sent by April 30, 1991 to: Head, Department of Surveying Engineering, The University of Calgary, 2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4.

Princeton University—Accelerator Engineer. Princeton University seeks an experienced accelerator engineer, or a high level technician with equivalent experience, for development and maintenance of the Princeton AVF Cyclotron. The cyclotron is a K•50 accelerator which produces protons and other light ion beams for the nuclear physics research program at Princeton. Experience with all aspects of the operation of a low energy nuclear physics accelerator is highly desirable, including high power rf electronics, power supplies, computerized control systems, ion sources,a and beam transport systems. The successful candidate will be expected to supervise a small technical staff and provide support to student and faculty researchers. Engineering or physics A.B., or equivalent laboratory experience is required. Send resume and references to Professor Frank Calaprice, Department of Physics, Princeton University, P.O. Box 708, Princeton NJ 08544. Princeton is an equal opportunity/affirmative action employer.

University of Hawaii at Manoa, Department of Electrical Engineering, invites applicants for tenure-track associate professor or assistant professor positions with specialization in any of the following three areas: (1) Computers: All aspects of parallel and distributed computing: e.g., architecture, systems, networking, software, and applications. (2) Electrophysics: Instrumentation, microwave engineering, and VLSI engineering. (3) Communications: Data networks. (4) Control: Theory and systems. Duties: Teach EE undergraduate and graduate courses, serve on university and department committees, serve on graduate student committees, conduct research and scholarly activities, and perform related tasks as assigned. Minimum Qualifications: Associate Professor: Ph.D. degree or completion of all requirements for a doctorate in electrical engineering; minimum of four years of full-time college or university teaching at the rank of assistant professor equivalent, with evidence of increasing professional maturity; demonstrated scholarly achievement in comparison with peers active in the same field; demonstrated ability to plan and organize assigned activities, including the supervision of work of assistants when appropriate; ability to pursue and supervise research; strong commitment to both undergraduate and graduate teaching. Assistant Professor: Ph.D. degree or completion of all requirements for a doctorate in electrical engineering; demonstrated ability to teach; demonstrated scholarly achievement; ability to pursue and supervise research; and a strong commitment to both undergraduate and graduate teaching. Salary negotiable dependent upon qualifications and experience. Send resume and three references by April 15, 1991 to: Professor Shu Lin, Chairman, Dept. of Electrical Engineering, University of Hawaii at Manoa, 2540 Dole Street, Holmes Hall 483, Honolulu, HI 96822.

Worcester Polytechnic Institute—The EE Department invites applications for tenure track faculty positions at the Assistant or Associate Professor level in the following areas: Computer Engineering, Data Communications, Ultrasonics, and Microwave devices. Candidates must possess an earned doctorate, and will be expected to have a strong commitment to high quality undergraduate and graduate engineering education, as well as to development of a research program. Applications from women and underrepresented groups are especially invited. Worcester Polytechnic Institute is a technical university offering project-oriented programs in Engineering, Science and Management, WPI is located in the high-tech region of central Massachusetts, with an enrollment of 2,500 undergraduate and 400 full-time graduate students. The EE department has 24 full-time tenure-track faculty, and strong undergraduate, graduate and research programs. Please send a statement of your research and teaching interests, a resume, and a list of three references with addresses and telephone numbers to: Dr. John A. Orr, Head, Department of Electrical Engineering, Worcester Polytechnic Institute, Worcester, MA 01609. WPI is an equal opportunity affirmative action employer.

Embry-Riddle Aeronautical University, Prescott, Arizona. Embry-Riddle Aeronautical University invites applications for the following faculty positions: Electrical Engineering—Ph.D. in EE is required. Preference will be given to candidates with experience in the design of avionics systems. Computer Science—Ph.D. in Computer Science or a related field is required. Preference will be given to candidates with a background in software engineering and a familiarity with the requirements of software design for aerospace applications. We offer a comprehensive compensation/benefits package. Send letter of interest, resume and name, addresses and phone numbers of three references to Dr. James Lyall, CS/EE, c/o Office of Human Resources, Embry-Riddle Aeronautical University, Prescott, AZ 86301. Women and minority group members are encouraged to apply. EOE.

University of Miami. The Department of Electrical and Computer Engineering invites nominations and applications for a faculty position at the Full Professor level. Preferred areas of interests are robotics and robot vision. Qualifications include a Ph.D. degree in electrical engineering or equivalent, experience in teaching undergraduate and graduate courses, and established record of publications and external funding. The University is located in Coral Gables, a suburb of Miami, Florida. Applications should be sent with the names of three references to: Dr. Tzay Y. Young, Acting Chairman, University of Miami, Dept of Electrical and Computer Engineering, P.O. Box 248294, Coral Gables, Florida 33124. The University of Miami is an equal opportunity/affirmative action employer.

University of Miami. The Department of Electrical and Computer Engineering invites applications for a tenure-track faculty position in computer engineering at the Assistant/Associate Professor level. Preferred areas of interest are operating systems, software engineering and database systems. Qualifications include a Ph.D. degree in computer science or computer engineering, and the ability of initiating research projects, attracting external funding, and teaching undergradaute and graduate

READER GUIDE TO PRODUCTS AND SERVICES

IEEE-USA's Precollege Education Committee Produces New Brochure

IEEE-U.S. Activities has published a "Directory of Volunteer Opportunities in Precollege Mathematics and Science Education for Engineers and Scientists." The Directory lists 31 education-related programs that rely heavily on the human resources of volunteers at the local level. For quick reference, a matrix specifies each program's intended audience and grade level, the particular tasks that a volunteer may be asked to perform, the time commitment involved, and any special qualifications required of the volunteer.

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The IEEE announces availability of POSIX.1.–1990, an IEEE standard defining standard application programming interfaces to basic operating system functions, such as I/O and process management. It is written in terms of the C Language. A revision to IEEE Std 1003.1–1988, this is the first POSIX standard to be approved as an ISO (International Standards Organization) standard: ISO/IEC JTC–1. It is being published by the IEEE as ISO IS 9945–1: 1990.

POSIX encompasses a range of standards under development by the IEEE to provide interfaces for application portability across multiple hardware and software platforms. Virtually every computer supplier and open systems specifier has adopted POSIX.

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READER GUIDE TO PRODUCTS AND SERVICES

ing processes used in semiconductor fabrication. Factors affecting the performance of the industry within the major national participants are discussed, and the relationship of the industry to science and technology is also considered. The book should be of interest to scientists and engineers, technical historians, and, indeed, anyone with an interest in the development of modern, all-pervading technology.

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IEEE's First Worldwide Member Opinion Survey Now Available

The IEEE's *1990 Member Opinion Survey* is now available to the public. The survey is an unprecedented worldwide effort by the IEEE to study professional, academic, and intellectual activities of all its members. Previous IEEE surveys were limited to members in the United States.

Among the IEEE United States Activities programs most important to respondents were professional publications, meetings, workshops, and programs influencing employer practices, the business climate, engineers' public image, and Federal policy. A majority of respondents, both in and outside the United States, urged the IEEE to exert increasingly more influence as a worldwide technical leader.

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SIX IEEE VIDEOCONFERENCES

The IEEE's Educational Activities Department has scheduled a half-dozen videoconferences for 1991. Their subjects and the dates they'll be transmitted are: "Uses of artificial intelligence in manufacturing," March 20; "Applications of fuzzy logic," April 26; "Uses of neural networks in the '90s," May 22; "Quality management," Sept. 19; "Software testing and reliability," Oct. 30; and "The technical development and future of optical computing," Dec. 11. Programs for the conferences are available free to IEEE members through their local Sections and for a fee to companies and universities.

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courses. Salary will be commesurate with rank and experience. The University is located in Coral Gales, a suburb of Miami, Florida. Applications should be sent with the names of three references to: Dr. Tzay Y. Young, Acting Chairman, University of Miami, Dept. of Electrical and Computer Engineering, P.O. Box 248294, Coral Gables, Florida 33124. The University of Miami is an equal opportunity/affirmatve action employer.

Tenure track Associate/Assistant Professor of Biomedical Engineering (BME) at Worcester Polytechnic Institute. WPI offers M.S. and Ph.D. degrees in BME. Close cooperation exists with the University of Massachusetts Medical School, Tufts University School of Veterinary Medicine, local hospitals and the Massachusetts Biotechnology Research Park. Ph.D. in BME or a related discipline required. Preferred areas of specialization are: biomedical signal processing and application of optics to biomedicine, but all specialities will be given consideration. Applicants should be able to teach a physiological systems course/laboratory. Applicants should be interested in developing a strong research program and be committed to quality teaching. WPI is located near the heart of the high technology focus of New England, yet offers opportunities for urban, suburban, or rural lifestyles. Send resume and names of three (3) or more references to: Dr. Robert A. Peura, Chairman, BME Dept., Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609. Tel: (508) 831-5447. FAX: (508) 831-5483. WPI is an affirmative action, equal opportunity employer.

Faculty position—Assistant Professor position and Associate Professor position in Electrical Engineering. The Division of Engineering, University of Texas at San Antonio invites applications for two tenure-track positions. A Ph.D. degree is required for both positions and successful candidates are expected to participate in both undergraduate and graduate teaching, and research activities. Applicant in all areas of electrical engineering are invited to apply, but the following areas are of special interest: digital signal processing, fault-tolerant computing, design for testability, telecommunications, solid state devices, VLSI. Salary will be commensurate with qualifications and experience. UTSA is a comprehensive, metropolitan university located in a rural setting on the edge of the Texas hill country. The city of San Antonio combines a rich cultural heritage with modern focus on education, research and technology. Send resume and names of four references by April 2, 1991 to: Chair, Search Committee, Electrical Engineering, Division of Engineering, The University of Texas at San Antonio, San Antonio, TX 78285-0665. UTSA is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

University of Arizona, Systems and Industrial Engineering The Department ofSystems and Industrial Engineering at The University of Arizona invites applications for two tenure-track faculty positions, preferably at the rank of assistant professor. Candidates with an outstanding teaching and research record which synergistically complements the departments strengths may be considered for a senior level appointment. The department spans a broad range of interests related to systems and industrial engineering, including methods related to systems theory and integration, computational software engineering, optimization, applied probability, and engineering statistics; and modeling applications related to manufacturing, telecommunication, human-machine systems, natural resources, and service systems. Although all candidates with demonstrably strong research and teaching potential in these areas will be considered, we especially encourage applications from candidates whose research interests include or complement one or more of the following: 1) Applied probability, with interests in telecommunications, computer networks, reliability, manufacturing, or decision theory. 2) Software and algorithms for manufacturing (concurrent design, information systems, CAD/CAM, human-computer interface, simulation, production systems, etc.) Applicants should hold a doctoral degree in an area related to systems and industrial engineering by September 1, 1991, and should submit their curriculum vitae and names of three or more references to: Professor Duane Dietrich, Chairman, Faculty Search Committee, Systems and Industrial Engineering Department, The University of Arizona, Tucson, AZ 85721. Applications will be accepted until April 1, 1991, or until the positions are filled. The University of Arizona is an equal opportunity/affirmative action employer.

Assistant/Associate Professor, Electronics and Computer Technology, Telecommunications and Computer Systems. The faculty member will develop and teach courses in the areas of telecommunications and computer systems and conduct applied research for government and/or industry. The successful applicant will be prepared to participate in a full range of activities: teach, research and service; direct Masters degree candidates; advise undergraduate students; and assist industry and the general public through technology transfer. Salary is negotiable. This position requires a doctorate in Electrical Engineering or equivalent, and three to five years of applicable industrial experience with telecommunication systems design and digital and computer systems applications. A minimum of two years of teaching experience and three years of industrial experience with telecommunication systems design are desired. Closing date will be the 22nd of each month until position is filled. To apply, send vitae and a list of at least three references with telephone numbers to: Dr. Albert L. McHenry, Chair, Department of Electronics and Computer Technology, Arizona State University, Tempe, AZ 85287-6606. An Equal Opportunity/Affirmative Action Employer.

The University of Alabama at Birmingham, Department of Biomedical Engineering. The Department of Biomedical Engineering invites applications for a tenure-track position at the rank of Assistant Professor beginning in the fall of 1991. Preference will be given to candidates with research experience in bioinstrumentation. Candidates with a bioinstrumentation background which includes some aspect of MRI instrumentation are of particular interest. Duties will include teaching, research, the development of bioinstrumentation courses, and the development of bioinstrumentation laboratory facilities. The Department of Biomedical Engineering at the University of Alabama at Birmingham offers graduate programs leading to the M.S. and Ph.D. degrees. Primary research areas are in biomaterials, biomechanics, bioinstrumentation, biotechnology and medical imaging. UAB is an autonomous campus within the University of Alabama system, UAB faculty currently are involved in over $100 million of externally funded grants and contracts. A 4 Tesla clinical NMR facility for cardiovascular research is presently being established, making it the most advanced of its type in the world. In addition, the Department has on-line access to a Cray XMP/24 supercomputer through the Alabama Supercomputer Network. The UAB environment offers an excellent opportunity to pursue research and educational activities in biomedical engineering in collaboration with outstanding scientists in a variety of areas. Applicants must be U.S. citizens or have permanent U.S. residency, and must have an earned doctorate in biomedical engineering or a related field. Interested persons should send an application letter, a current vita, copies of important publications (if applicable), and research interests, and the names of three references to Professor Ernest Stokely, School of Engineering, University of Alabama at Birmingham, BEC 256, Birmingham, AL 35294. Applications will be accepted until the position is filled. The University of Alabama at Birmingham is an equal opportunity, affirmative action employer, and encourages applications from qualified women and minorities.

Stocker Visiting Chair in Electrical and Computer Engineering at Ohio University. Applications and nominations are being accepted for the position of Stocker Visiting Professor in Electrical and Computer Engineering (ECE). The ECE Department at Ohio University has twenty full-time and four part-time faculty, 450 undergraduate students and 80 graduate students. External research support in ECE exceeds $2.3M per year, a large portion of which comes via the Avionics Engineering Center, a unit of ECE. The ECE Department is housed in the $15M Stocker Engineering Center. The Stocker Chair position is supported through the Stocker Endowment, presently worth more than $13M. Qualifications for consideration for the Stocker Chair position include noteworthy achievements in research and teaching or industry/government. The individual selected for this position is expected to teach, participate in Departmental research, and be available to present and conduct invited seminars/lectures at various universities, including O.U. The maximum term of appointment for this position is three years; a lesser term can be negotiated. Stocker Professors are provided part-time secretarial support, a travel allowance, special office accommodations, and equipment/supplies support, if needed. In addition, modest furnished living quarters, specifically designated as Stocker Chair Apartments, are available for Stocker Professors and their spouses. Salary for the position is negotiable. The ECE Stocker Chair position is ideal for a person who wishes to take leave from his/her present employer. Applications and nominations will be accepted until the position is filled. Please send a resume with at least three references or your nomination to Dr. Jerrel R. Mitchell, Stocker Center, Ohio University, Athens, OH 45701-2979. Preference will be given to U.S. citizens and permanent residents. Ohio University is an equal opportunity and affirmative action employer.

New Zealand University of Canterbury. The University invites applications for the following position: Professorship in Communications—Department of Electrical and Electronic Engineering. Applicants should have appropriate teaching and/or research experience in one or more of the following areas: communications theory, coding, mobile communications, wave propagation, computer communications, communications networks, optical communications, however candidates with a proven record in any other area of Information Technology will be considered. The successful candidate will be expected to provide leadership at both the undergraduate and graduate level. Maintenance of international links, industrial co-operation and involvement in contract research are considered important aspects of this activity. As a place to live, Christchurch has much to offer with both modest living and housing costs, good schooling and unparalleled recreational opportunities. The salary for a Professor is within the range NZ$80,080 to NZ$99,840 per annum which is in the top 5/of salaries for New Zealand. Applications close on 31 May 1991. Further particulars and Conditions of Appointment may be obtained from the undersigned. Applications, quoting Position No. EE50, must be addressed to: A.W. Hayward, Registrar, University of Canterbury, Private Bag, Christchurch, New Zealand. Telephone 64 3 642 808 or Fax 64 3 642 999. The University has a policy of equality of opportunity in employment.

Faculty Position—Cooper Industries Professor of Electrical Engineering: the Electrical and Computer Engineering Department at Ohio University is continuing its search for a senior tenure-track faculty member. The Cooper Industries Professor of Electrical Engineering will be expected to teach and develop a sponsored research program in power electronics and/or industrial controls. A demonstrated ability to interact with industrial sponsores is essential. The successful candidate is expected to take a leading role in developing a multi-disciplinary program in computer-integrated manufacturing. Candidates must have an earned Ph.D. in engineering, a demonstrated record of teaching (undergraduate and graduate) and significant experience in promoting and conducting sponsored research. Interviews will continue until the position is filled. Send resume and a list of four reference to H.W. Hill, Jr., ECE Department, Ohio University, Athens, OH 45701-2979. Ohio University is an equal-opportunity, affirmative-action employer.

University of NSW, Australia. Applications are invited for a position of Research Fellow in the Dept. of Computer Science at University College, University of NSW at the Australian Defence Force Academy in Canberra. The position is funded by a research grant of the Australian Research Council and is tenable for 2 years starting immediately. The successful candidate will be a member of the Speech Research Group of the Dept and work on the evaluation of auditory models for automatic speech recognition systems. Facilities include 2 Pyramid 9810X, a Convex C120, a Masscomp 5500, a large number of Sun and 386 workstations, an Ariel DSP-16, ILS and Audlab. A PhD in computer science or equivalent is required, preferably with a background in speech research. Salary: A$33,163—A$40,257. Enquiries: Dr. M. Wagner, Tel.: Int+61-6-2688955, Fax: Int+61-6-2688581, AARNet: miw@csadfa.cs.adfa.oz.au. Applica-

tions quoting Z850304 should be sent to the Asst. College Secretary (Personnel), University College/ADFA, Canberra ACT 2600, Australia, by 12 April 1991.

Purdue University Schools of Materials Engineering and Electrical Engineering. The Schools of Materials Engineering and Electrical Engineering at Purdue University invite applicants for the Turner Professor of Engineering. The Turner Professorship is a tenured, joint appointment at the full professor level in the two Schools. Applicants must have an earned doctorate degree and be recognized as a leader in some aspect of electro-ceramics. The two Schools have strong disciplinary teaching and research programs. In Electrical Engineering, there are major research programs in many areas fundamental to the field including Circuit Theory, Electromagnetic Fields and Electro-Optics, and Microelectronics. Materials Engineering research programs center around the cornerstones of the field: Structure, Properties, Processing, and Performance. The two Schools have a long and successful program in interaction in many solid state areas, including eletro-ceramics. Among the supporting facilities for the area are: Turner Laboratory for Electro-ceramics, Solid State Devices and Materials Laboratory, X-ray Facility, and the Microstructural Analysis Facility. Interactions also exist with other programs and facilities throughout engineering and science, notably the NSF Engineering Research Center for Intelligent Manufacturing Systems and the Centers for Superconductivity. The individual selected will be expected to be a recognized leader in some aspect of the broad area of electro-ceramics. Examples of areas would include fundamental ones such as defect structures related to physical behavior or some processing method to control chemistry and morphology. Interests in current topics such as high Tc superconductors, ferroelectrics,and thick films, as well as the broad areas of hybrid microelectronics and electronic packaging will be considered. Successful candidates will also be expected to teach both undergraduate and graduate courses, especially in the individual's area of expertise, to supervise MS and PhD projects, and to establish a strong research program. Several opportunities exist to develop multi-investigator programs, and interest/leadership will be a factor considered. The position is available and is expected to be filled during the 1991-92 academic year. All interested persons should submit an application prior to May 1, 1991 for full consideration. The search will continue until the position is filled. Resumes and names of three references should be sent to: Turner Professor Search Committee, School of Materials Engineering, MSEE Building, Purdue University, West Lafayette, IN 47907. Purdue University is an Equal Opportunity/Affirmative Action Employer.

The Ohio State University, Department of Electrical Engineering invites applications for tenure-track faculty positions. One position is open in microelectronics at any level. At present there are 10 faculty members directly involved with the microelectronics laboratories. A new 4000 sq. ft. clean room is in development. The primary areas of interest are microstructure processing and/or VLSI circuit design. Another position is open in communications at the assistant professor level. The Department has almost 50 faculty members and is engaged in extensive research activities with over $6 million per year in funded research. Applicants must have a Ph.D. degree in Electrical Engineering or a related field, outstanding academic credential, potential for developing research programs, and an interest in teaching at the undergraduate and graduate levels. Send resume and the names of three references to: Daniel B. Hodge, Chairman, Department of Electrical Engineering, The Ohio State University, 2015 Neil Avenue, Columbus, Ohio 43210. The Ohio State University is an equal opportunity/affirmative action employer.

Electrical Engineering Technology. The State University of New York College of Technology at Alfred seeks applicants for a tenure-track faculty position for the Fall 1991 semester in the Department of Electrical Engineering Technology. The department offers TAC/ABET accredited associate degree programs in Electrical Engineering Technology and Electro-Mechanical Engineering Technology, and an AS degree program in Engineering Science, plus Bachelor of Technology degree programs in Electrical and Electromechanical Engineering Technology as an extension center of SUNY Binghamton. Minimum qualifications are bachelor's and a master's degree in Electrical Engineering, Electrical Engineering Technology, or a closely related engineering discipline. Three years of college-level teaching experience and/or three years of industrial experience in any of these disciplines is preferred. Professional registration is desirable. Rank and salary are commensurate with qualifications. Starting date is August 21, 1991. The position requires expertise in two or more of the following areas: circuits, analog and digital control systems, electronic communications, electromechanical systems, analog electronics, microelectronics. Position involves teaching at both the AAS and BT levels, academic advising and university service. Applicants should show evidence of teaching and scholarly abilities that match department goals. Applications will be accepted until position is filled. Review of applications will begin immediately. Send application with resume and the names and addresses of three references to: Ms. Sally Doty, Director of Personnel and Affirmative Action, SUNY College of Technology, Alfred, NY 14802. SUNY is an Equal Opportunity/Affirmative Action Employer.

Utah State University, Electrical Engineering: Applications for two (2) tenure track faculty positions are invited for appointment in the Electrical Engineering Department at Utah State University. Candidates must have a Ph.D. in Electrical Engineering. Experience or a demonstrated potential for teaching undergraduate and graduate courses and performing research is expected. Openings for assistant, associate and professor are available. Research and teaching expertise in one or more of the following areas is preferred: Communications and signal processing, Atmospheric Space Science, VLSI and MMIC, and optical communications. The Electrical Engineering Department currently graduates 60 BS students, 15 MS and 2 PhD students per year. USU is located in Logan, Utah (population about 35000) in beautiful Cache Valley having both summer and winter sporting activities. Applications will be accepted beginning January 20, 1991 and continue until the positions are filled or until January 20, 1992. Send resume and names of three references to Dr. Richard W. Harris, Electrical Engineering Department, Utah State University, Logan, UT 84322-4120. USU is an EO/AAE.

Department of Electrical Engineering of Northern Illinois University, invites applications for tenure-track Assistant and Associate Professor positions for fall 1991 semester in the areas of: semiconductor device fabrication, communication systems and optics, and electromagnetics. Successful applicants will be required to teach at both undergraduate and graduate levels, pursue funded research and work with local industries in their fields. Qualifications include doctorate in Electrical Engineering, significant academic leadership experience, a demonstrated record of teaching and research, scholarly publications, U.S. citizenship or permanent U.S. residency required. Salary, rank and tenure status will be commensurate with qualifications and accomplishments. Applications will be reviewed as received and will continue until all positions are filled. Clearly identify the particularly specialization in your letter of application. Send letter of application, resume, names of three references and copies of recent publications to Professor Alan P. Genis, Chair, Department of Electrical Engineering, Northern Illinois University, DeKalb, IL 60115. Northern Illinois University is an Equal Opportunity, Affirmative Action Employer.

University of South Carolina, Department of Electrical and Computer Engineering, invites applications for tenure-track faculty positions. Particular areas of interest include quantum and physical electronics, computer architecture and computer vision. Persons of high caliber in other areas will also be considered. Appointment will be at the Assistant or Associate Professor level with a competitive salary and rank commensurate with qualifications. Tenured appointments at the level of Professor are also possible for uniquely qualified individuals. The USC, as the flagship university of the state, seeks candidates having a strong commitment to excellence in both education and research. Candidates for Associate Professor are expected to show strong research potential. Positions will remain open until suitable candidates are found. Applicants should send resumes, including names of at least three references, to Professor Etan Bourkoff, Chair, Department of Electrical and Computer Engineering, Swearingen Engineering Center, University of South Carolina, Columbia, SC 29208. The University of South Carolina is an equal opportunity/affirmative action employer.

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Positions Open

Help Wanted: Lead System Software Engineer, Networking Group. By 2/27/91. Please send resume to: Employment Security Department, ES Division, Att: Job #244170, Olympia, Washington 98504. Job Description: Designs, implements and tests complex and high level systems and software for micro computers. Assumes lead responsibility to design and coordinate testing of high level local area networking system software utilizing LAN Man, MS-DOS and Windows operating systems and "C" programming languages. Develops testing programs for networking environment using graphical user interface programs in a Windows environment. Assumes major project responsibility including: 1) requirements and analysis of project specifications; 2) product design; and 3) implementation schedules. Requirements: B.A. or B.S. in Electrical Engineering, Computer Science, Physics or Mathematics. Two years of work experience in computer design or programming writing GUI programs in a windowing environment. This must include six months or work experience in computer design or programming utilizing LAN Man or a networking operating system and MS-DOS operating system, and "C" language and directing others to test and debug software. Must have legal authority to work in the United States. Job location: Redmond, Washington. Salary: $40,500-42,000 per annum, depending on experience 40 hours per week, flex time. EOE.

Computing Systems Analyst for NE Ohio hospital to design, develop, & modify computer systems & data bases for use in real-time computer environments on several multiuser minicomputer systems using Fortran & "C" languages, including system security & control procedures, user training requirements, testing plans & quality assurance standards & procedures; consult with users to determine systems objectives, specific data retrieval & analysis requirements; present findings, recommendations & specifications to the users after analysis; guide & monitor system implementation; train users; delegate circumscribed modules to programmers; restructure data base & modify existing programs; recommend future enhancements to systems; draft manuscripts for presentation at technical meetings. No exp. req. in above duties but applicants will qualify with an M.S. in Electrical Engineering (must have taken 1 course ea. in Computer-Aided Analysis & Design of Network & Digital Processing with 2 courses ea. in Network Syntheses; undergraduate degree must be in Mathematics). M-F 8:00AM-5:00PM. $29,165/yr. Must have proof of legal authority to work permanently in U.S. Send resume in duplicate (No Calls) to J. Davies, JO#1255649, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

Electronic Engineer for NE Ohio biomedical sensor research, development & manufacturing firm to design sensing devices, electronic measurement circuits, digital logical & timing control circuits, mechanical structures for sensors, & printed circuit board layout; design & fabricate fiber optics sensor for blood pressure measurement. Requires 2 yrs. exp. in above duties (in lieu of exp. in designing & fabricating fiber optics sensor for blood pressure measurement, at least 2 publications in the field of fiber optics sensors is acceptable) & an M.S. in Biomedical Engineering (Must have thesis in

the field of fiber optic sensors; must have taken at least 1 course ea. in sensors, design of precision instruments, system & signal analysis in life science, digital signal processing, & digital control systems). M-F 8:30AM-5:00PM. $37,145/yr. Must have proof of legal authority to work permanently in U.S. Send resume in duplicate (No Calls) to J. Davies, JO#1266648, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

Help Wanted: Senior System Software Engineer, Networking Business Unit. By March 31, 1991, Please send resume to: Employment Security Department, ES Division, Att: Job #242293, Olympia, Washington 98504. Job Description: Designs, implements and tests complex and high level systems and software for micro computers. Assumes senior responsibility to design parallel systems software for LAN Man operating system utilizing OS/2 operating system and Assembler languages. Designs and implements user interface for parallel system. Assumes major project responsibility including: 1) requirements and analysis of project specifications; 2) product design; and 3) implementation schedules. Two positions available. Requirements: M.A. or M.S. in Electrical Engineering, Computer Science, Mathematics for Physics. Six months of work experience in computer design or programming utilizing parallel programming for a multitasking operating system and assemble languages. Must have proof of legal authority to work permanently in the United States. Job location: Redmond, Washington, Salary: $37,500-40,000 per annum, depending on experience 40 hours per week, flex time. EOE.

Video Systems Engineer. Design and develop real time software system for animation control of proprietary hardware. Design interface between software and hardware for animation and control of 2-1/2 dimensional graphic system. Design character and phrased based input system for traditional and simplified Chinese languages. 40 hrs/wk, 8-5, $3,000/mo. Bachelors of Science degree in Electrical Engineering or Electronics. Proven ability to (1) Read, write and type in Traditional and Simplified Chinese languages and (2) Analyze, design and implement array processing software systems for digital signal processing applications. Send resume and proof of legal authority to work in the U.S. to: Colorado Dept. of Labor, 600 Grant Street, #900, Denver, CO 80203 and refer to Job Order Number CO3195343.

Scientific Linguist. Plan, develop, analyze and compare natural speech data and synthetic speech data in English, German, French and Spanish for the purpose of devising improved computer algorithms and codes to meet voice quality requirements for text to speech products. Ph.D. or equiv. in Linguistics. University training, research or experience with acoustic phonetics, speech syntheses, articulatory phonetics, and use of computers for speech analysis. $4120/mo. Job site/interviews: Albany, CA. Clip an and send w/resume to Job Order # SK19861, P.O. Box 9560, Sacramento, CA 95823-0560 no later than March 31, 1991.

Help Wanted: Product Manager. Send Resume on or Before 3/31/91 to: Employment Security Department, ES Division, Job #245802-S, Olympia, Washington 98504. Job Description: Supervise introduction of new and existing products and direction to Product Specialist personnel, both domestic and foreign; the development and maintenance of specifications and data for company product lines; the preparation and maintenance of current application bulletins, specification sheets and related literature. Supervises the processing of technical inquiries, special modifications and requirements in coordination with customers, representatives, and manufacturing and design engineering personnel. Prepares, reviews and proofs sales mailings to representatives, both domestic and foreign, to assure current information for company and competitive products. Monitors sales performance and evaluates sales data to identify weak product lines and sales regions. Supervises field training of representatives regarding systems applications and technical capabilities of Company products. Provides technical support to the sales force in the market area. Supervises promotional materials and participation in the development of the advertising program for respective product lines. Prepares basic rationale for pricing reviews and performs other duties as required. Requirements: B.S. in Electrical Engineering plus two years industry experience as marketing manager and/or product support manager in precision electronic instruction field, or two years' experience in job offered. Must be willing to travel foreign and domestic 35-40/of working time. Salary: $1,038.40 per week, with no overtime. Position Offers: Prevailing working conditions, 40 hours per week, 8:00 a.m. to 5:00 p.m., Monday through Friday. Position in Everett, Washington On-the-job training not offered, equal opportunity employer, must have legal authority to work permanently in the United States.

Engineer, CAD Engineer,Senior. Design/develop software to enhance circuit simulation capabilities and device modeling; research next-generation simulation algorithms. Ph.D. in Electrical Engineering. Academic project/research background in VLSI circuit simulation, hierarchical waveform and numerical analysis techniques, device modeling, SiMOS, bipolar and GaAS MESFET technologies, C, FORTRAN, UNIX, and circuit design CAD tools, including SPICE, ADVICE, RELAX,and MOTIS; academic coursework in VLSI digital systems design, microprocessor based systems, bipolar devices and circuits and semiconductor physics. $4,600/mo.; 40 hrs/wk. Place of employment and interview: Santa Clara, CA. If offered employment, must show legal right to work. Clip ad and send with resume to: Job No. MD 21056, P.O. Box 9560, Sacramento, CA 95823-0560 not later than March 31, 1991. The company is an equal opportunity employer and fully supports affirmative action practices.

Electromagnetic Analyst. The MacNeal-Schwendler Corporation, the leader in finite element technology and software products for over 25 years, is seeking a MSEE with 2-5 years experience in the design of electrical apparatus and in electromagnetic field analysis. This challenging position is in the Engineering/Electromagnetic Department of our Milwaukee Office. Duties include: application of MSC/EMAS—the world's most advanced 3-D finite-element analysis code—to a wide variety of electrical problems; teach field analysis seminars; conduct on-site EM workshops at various locales, and conduct various consulting investigations for clients. Preferred candidates will have demonstrated expertise/interest in electromagnetics, finite element analysis, computer-aided engineering, and project management. Candidates must have the ability to prepare and communicate technical issues concisely and clearly. We offer competitive salaries and an outstanding benefit package. Qualified applicants should submit their resumes to: The MacNeal-Schwendler Corporation, 815 Colorado Blvd., Los Angeles, CA 90041, Attn: Human Resources. Equal Opportunity/Affirmative Action Employer.

Growing high tech company seeks an experienced engineering professional. Minimum of BSEE and 3 years experience in product design and development required. Experience in high speed analog and digital circuit design, real time micro-processor based systems, FORTRAN programming, and high level operating systems (eg. VMS) is required. Background in radiation detection and measurement also suggested. Position requires some travel to provide technical expertise in operating innovative process monitoring equipment. IDM Corporation is an Austin, TX based manufacturer of process Monitoring systems. Qualified parties are invited to send a resume with salary history to: IDM Corporation, 1901 Rutland Drive, Austin, Texas 78758, Attn: Personnel Department. IDM Corp. is an equal opportunity employer.

Sr Research Scientist to design and develop ICs utilizing SOI, HEMT and HBT technologies. Must have PhD level education in solid state electronics, at least 3 yrs experience in semiconductor device fabrication and characterization at room and cryogenic temperatures. Knowledge of CMOS processing, SOI, HEMT and HBT technologies with good publication record. Place of Employment & Interviews Torrance, CA rate of pay $826.92 per week. Send this ad and a resume or letter of qualifications to job #WS12037 P.O. Box 9560, Sacramento, CA 95823-0560 not later than March 31, 1991.

Engineer, Software—Use C, AXON on X-Windows, UNIX/SUN, SPARC/3, MS-DOS/IBM-PC to design & develop software for image processing/ chips & to participate in company's joint-venture (with Japan) research & development team for the design of systolic and VLSI neural network integrated circuits and the techniques of image analysis. Requires: Ph.D. Computer Science, 3 yrs job exp or 3 yrs exp in Design, research & development of neural network. Must be fluent (read, write & speak) in Japanese. Must be willing to work in Non-smoking work environment. $55,000/yr 8am-5pm 40hr/wk. Job Site & Interview: San Diego, CA. Send this ad & resume to: JO#EG14016. P.O. Box 9560. Sacramento, CA 95823-0560. No later than 3/31/91.

Engineer/Technology Consultant. Responsible for applied research related to broadband metropolitan area network (MAN) and high speed data service on topics such as: analysis and assessment of laboratory model of MAN, R&D of network management capabilities over MANs and other high speed data networks, and R&D of high speed processing capabilities to interconnect MANs, local area networks (LANs) and wide area networks. Also responsible for influencing university and Bellcore research and standards process through technical contributions. Minimum requirements: Ph.D. or equivalent in Electrical Engineering, 3 yrs in position offered or 3 yrs in field of electrical engineering which must include at least 2 yrs research experience in development/analysis of LAN, MAN or broadband network technology and 2 yrs experience in design/analysis of computer communication networks and data network management. Salary: $1,038/wk. Job Site: San Ramon, CA. Send this ad and resume to Job # SK19925, P.O. Box 9560, Sacramento, CA 95823-0560, no later than March 20, 1991. If offered employment must show legal right to work in U.S.

Software Engineer: Resp. for defining & developing the strategy & implementation of modeling, performance analysis, & evaluation of computer networks. Duties incl. developing performance models for computer communication architecture analysis; developing tools for performance measurements; developing modeling project plans, & related duties. Reqs PhD in Electrical Engineering w/2 yrs of exp. in job offered or in research in modeling & performance analysis of computer networks. Also reqs. exp. w/application of stochastic modeling/queuing theory in communication systems & computer network modeling & analysis; simulation techniques & tools; & local area & high speed computer network architectures. Salary: $1,000/wk. 40 hrs/wk. Job site/intvw site: Sunnyvale, CA. Send ad and resume to Job BW9011, Employment Department AJL 0122, PO Box 9560, Sacramento, CA 95823-0560 no late than April 4, 1991. Must have legal right to work.

Research and Development Engineer/Networking Software. As member of research and development team involved in development of datalink and network layer protocol analyzer designed around multiple microprocessors, design, develop, architect, prove feasibility and practicality, code, integrate, test and validate: graphical user interface system, resource compilers and pieces of multi-tasking operating system; real time displays and port processing displays of decoded datacommunication protocols; performance analysis, protocol verification and conformance testing; protocol analysis and customized application software. Perform networking software research and development tasks requiring design in C++ and use of concepts of artificial intelligence. Coordinate with other groups to design and develop product requirements. Requirements: Bachelor and Master of Science Degree in Computer Science. Education, training, and/or experience must include: use of UNIX; design and implementation of networking software and data communication protocols; design and use of a graphical user interface system; real time applications and programming on microprocessors; assembly and C language programming; artificial intelligence; operating system programming on PCs and workstations; and formal course work in modern compilers, data structures and networking concepts including Reference Model of OSI, packet switching and circuit switching theory, WANs and LANs. 8:00 a.m. to 5:00 p.m., 40 hours per week. $40,200.00 per year. Reply by resume to: Jim Shimada, Colorado Department of Labor and Employment, 600 Grant Street, Suite 900, Denver, Colorado, 80203-3528. Refer to Job order #CO3195342.

Help Wanted: Project System Software En-

gineer, Advanced Technology/Business Development Group. By 4/1/91 Please send resume to: Employment Security Department, ES Division, Att: Job #245447, Olympia, Washington 98504. Job description: Designs, implements and tests complex and high level systems and software for micro computers. Assumes project responsibility to design prototype high level systems and software to determine feasibility of projects involving novel computer architecture, and computer architecture requirements for running 286-based real-time software, including a software modem, utilizing digital signal processing. Will utilize 86 Assembler Series, and "C" languages, and UNIX & XENIX operating systems. Assumes major project responsibility including: 1) requirements and analysis of project specifications; 2) product design; and 3) implementation schedules. Requirements: Master's degree in electrical engineering, computer science, physics, or mathematics. Two years of design project responsibility in design and development of compiler systems for prototype hardware and operating systems and 286-based real-time operating systems, to include six months of "C" and 86 assembler languages, and UNIX and XENIX operating systems and design of digital signal processing software to implement a modem. Must have legal authority to work in the United States. Job location: Redmond, Washington, Salary: \$64,000—\$68,000 per annum, depending on experience 40 hour per week, flex time. EOE.

Electrical Engineer. Will conduct research, design & development for advanced VLSI communication & signal processing devices, including theorem & algorithms investigation, architecture, logic, & circuits design, analysis, & simulation; develop future products & provide solutions to isolated but undefined problems in VLSI design & testing. Requires: Ph.D. in Electrical Engineering. Advanced academic background & research to include: digital signal/image processing, communication system & VLSI design; signal processing VLSI chip design, simulation & layout; design & simulation of high speed digital CMOS circuits, fast settling time Op-Amp, analog switch capacitor CMOS circuits; advanced digital integrated circuit design, advanced analog integrated circuits design (including switch capacitor circuits), network synthesis & filter design, VLSI system design, advanced circuits theory, digital signal processing, digital filter design, channel & source coding; communication engineering, algorithms & processing of communication system; CAD design tools; "C" language; board level design, implementation, & testing for digital signal processing circuits. \$4,000/mo. 40 hr. wk. Job site/Interview: Newport Beach, CA. Send this ad and your resume to Job #ET3029, P.O. Box 9560, Sacramento, CA 95823-0560, no later than April 1, 1991.

Software and Hardware Engineer 40 hrs/week. 8:00 a.m. to 5:00 p.m. Compensation: \$46,800/yr. Design and implementation of powertrain electronic controllers for automotive customers utilizing Motorola 68332 and 6811 microprocessors. Interpretation and documentation of single board electronic controllers software developed by automotive customers. M.S. in Elec Eng required. At least 22 mos. work experience as system engineer required. Educ must include at least 1 masters level course in control theory. Exp. as system engineer must include implementation of control theory algorithms in software on microprocessors. Employer paid ad. Send resumes to 7310 Woodward Ave., Rm. 415, Detroit, MI 48202. Ref. No. 96790.

Automotive Control Systems Engineer 40 Hrs/week. 8:00 a.m. to 5:00 p.m. Compensation: \$46,800/year. Design and implementation of control systems for automotive application based on techniques of nonlinear and robust control. Perform computer simulations to verify control designs. Communicate control algorithms to software and hardware engineers. Participate in software instrumentation and design reviews of control systems. PhD degree in Elec Eng required. Educ must include grad level research in nonlinear and robust control theory as evidenced by technical publications and/or PhD thesis. Employer paid Ad. Send resume to 7310 Woodward Ave, Rm. 415, Detroit, MI 48202. Reference No. 97590.

Chair, Department of Nuclear Energy

Brookhaven National Laboratory is a multidisciplinary laboratory located on Long Island, New York, managed by Associated Universities, Inc., under contract with the U.S. Department of Energy. We are seeking a distinguished engineer or scientist to serve as Chair of the Department of Nuclear Energy.

The Department of Nuclear Energy is one of the major scientific departments at Brookhaven. The activities of the Department include programs related to reactor development, operation and safety, and to development of neutral particle beams. The current effort includes theoretical and experimental studies on the safety of commercial nuclear power plants, development of designs for advanced, compact nuclear power plants, development of improved methods for safeguarding nuclear materials, nuclear waste management studies, compilation and evaluation of nuclear data required for users throughout the world, and construction and operation of a Radiation Effects Facility and the Neutral Particle Beam Facility.

The Department, with a staff of 330, is organized into eleven divisions. The majority of the funding for the Department's activities is provided by the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy.

Candidates are expected to be recognized authorities in the nuclear sciences field, and have contributed to the literature of nuclear energy. It is desirable that candidates have a Ph.D. in engineering, physics or chemistry; have extensive experience in both a research environment or an applied or industrial environment; be proven managers; have a successful record of working with program managers at government agencies, universities, and industrial organizations; and be able to bring to Brookhaven new opportunities for the Department's growth. Expressions of interest, which should include a resume and publications list, may be sent to: DNE Search Committee, Building 197C, Brookhaven National Laboratory, Associated Universities, Inc., Upton, Long Island, New York 11973. Attention: Dr. J.M. Hendrie. Equal Opportunity Employer M/F.

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invites applications and nominations for the position of Dean of the Purdue School of Engineering and Technology. The successful candidate will have an earned doctorate in engineering or related fields, have an established record of research and teaching sufficient to merit the rank of professor in the School, have proven administrative experience, and demonstrate an understanding of the relationship between engineering and technology programs. The School has 70 full-time faculty in eight departments offering coursework leading to Purdue University degrees in technology and engineering, including masters degrees in electrical and mechanical engineering. Two new facilities are under construction and should be completed in 1993. Review will begin in March 1991 and continue until the position is filled, preferably by June 1991.

Send nominations or applications to:

Professor Thomas Lenz
BS 3024C
IUPUI
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Scanning
The Institute

IEEE budget controls

The 1991 Board of Directors, at its first meeting on Jan. 30–31, devised a set of budgetary guidelines for the next three years with the goal of ensuring a surplus with which to replenish declining liquid reserves and to support new projects. To make operating funds available for some new needed ventures, facilities, and equipment, liquid reserves have been tapped and so have fallen to under $2 million. For this year, the guidelines require major Boards and Committees to balance their budgets on a month-by-month basis, and under no conditions to exceed the overall budgeted deficit of $550 000 [THE INSTITUTE, March, p.1].

High tech in the Gulf war

The highly visible success of the cruise missile, stealth fighter, and Patriot antimissile missile in the opening round of the United Nations' war against Iraq was due in part to unseen support from a network of computers, sensors, and satellites. Meantime, airborne radar systems like Awacs and JSTAR provided continuous tactical surveillance. One eventual outcome might be a new association in the public's mind between high-technology weaponry and reliable precision, rather than glitch-filled expense [THE INSTITUTE, March, p.1].

German, Japanese firms ally

Surging Japanese investment in Germany hit US $1.08 billion in 1989, in part because the country is seen as an ideal base for exploring Eastern Europe and the USSR, and also to enlarge Japan's entree to the European Community. The latest major venture is a strategic alliance between Daimler-Benz AG and Mitsubishi Corp. [THE INSTITUTE, March, p.1].

SiC to go commercial

Hard-to-melt silicon carbide can at last be grown in single-crystal form, thanks to a modified sublimation process. So researchers under the auspices of the National Aeronautics and Space Administration are developing the heat-tolerant devices for applications on turbine engines, large space power systems, and radar systems for high-temperature and chemically hostile environments [THE INSTITUTE, March, p.3].

AT&T'S unkind cut

One of the four major AT&T links out of New York City—an optical-fiber cable handling more than 100 000 telephone calls—was cut in error mid-morning on Jan. 4 by a workman and not repaired until late afternoon because of further errors. Various New York stock and commodities exchanges, as well as voice and data communications used by air-traffic control facilities in the New York City, Boston, and Washington, D.C., areas, were crippled for upwards of 3 hours. AT&T was to report in March on the disruption to a New York City task force on the reliability and coordination of metropolitan-area networks [THE INSTITUTE, March, p.1].

Coming
in Spectrum

SMART CARS ON SMART HIGHWAYS. Intelligent vehicle highway systems would shorten travel time, cut down on accidents, and reduce fuel consumption and pollution. This three-part article describes the ideal goals of such a system, what is in prospect in countries around the world, and socioeconomical problems.

CHALLENGES OF DIGITAL HDTV. Three of the simulcast HDTV systems proposed for U.S. terrestrial broadcasting are all digital and adopt varying approaches to video bandwidth compression, motion compensation, and modulation.

MILITARY SCIENTIST. For half a century, Ivan Getting has devoted his scientific talents to the U.S. defense effort. He advised War Secretary Stimson during World War II on how the U.S. Army should use radar, and later became heavily involved with missile development.

JAPAN'S NUCLEAR POWER. To reduce its dependence on energy imports, Japan plans to be generating 43 percent of its electricity by 2010 from nuclear power stations, up from 26 percent today; to grow more of its own nuclear fuel; to reprocess more spent nuclear fuel at home; and to innovate in reactor technology.

WORKSHOP ON WORKSTATIONS. This section's four major topics will concern:

- The ergonomics of the engineering environment, which should minimize eye and wrist strain and exposure to CRT radiation, for instance.
- Selection of a workstation for ease and efficiency of use in relation to: the type of work to be done; general hardware considerations, including workstation architecture; software; user performance; the local-area network; and network resources.
- Boards and peripherals used to upgrade workstations, and the bus and channel architectures available to integrate them.
- The impact of very large-scale ICs on the performance of servers and workstations.

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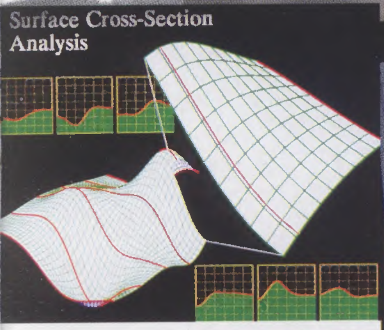

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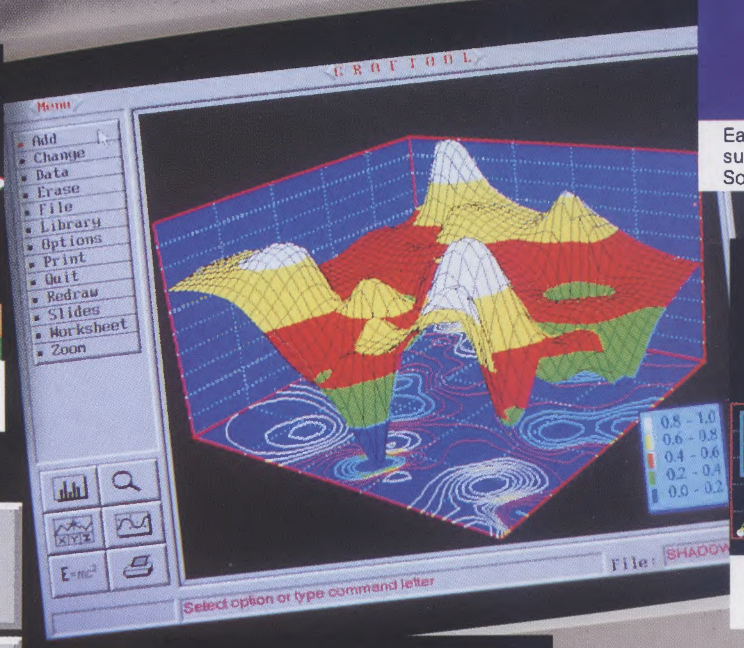

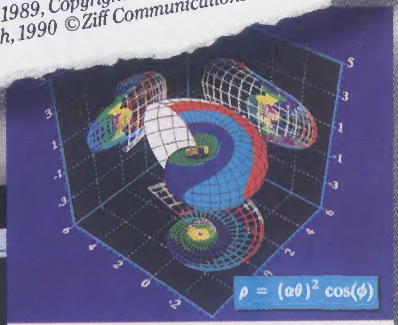

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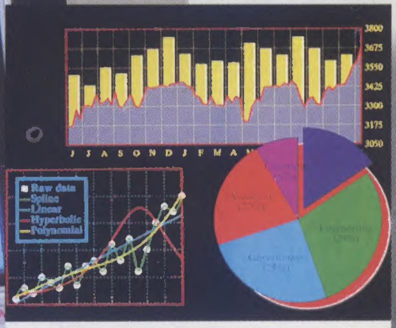

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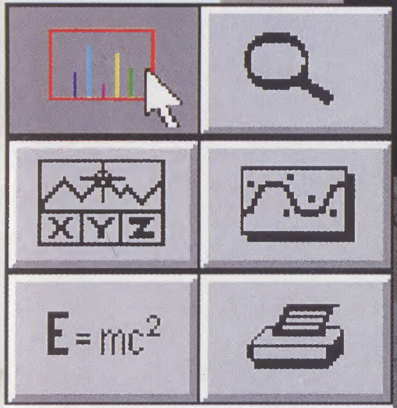

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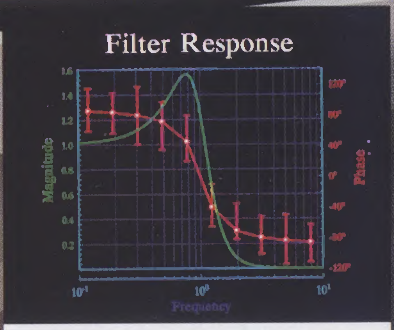

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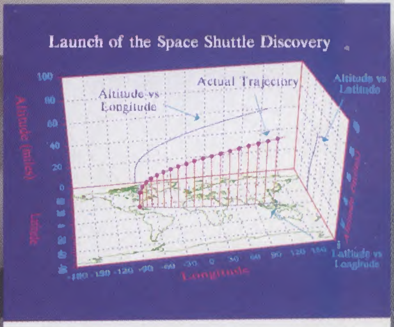

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